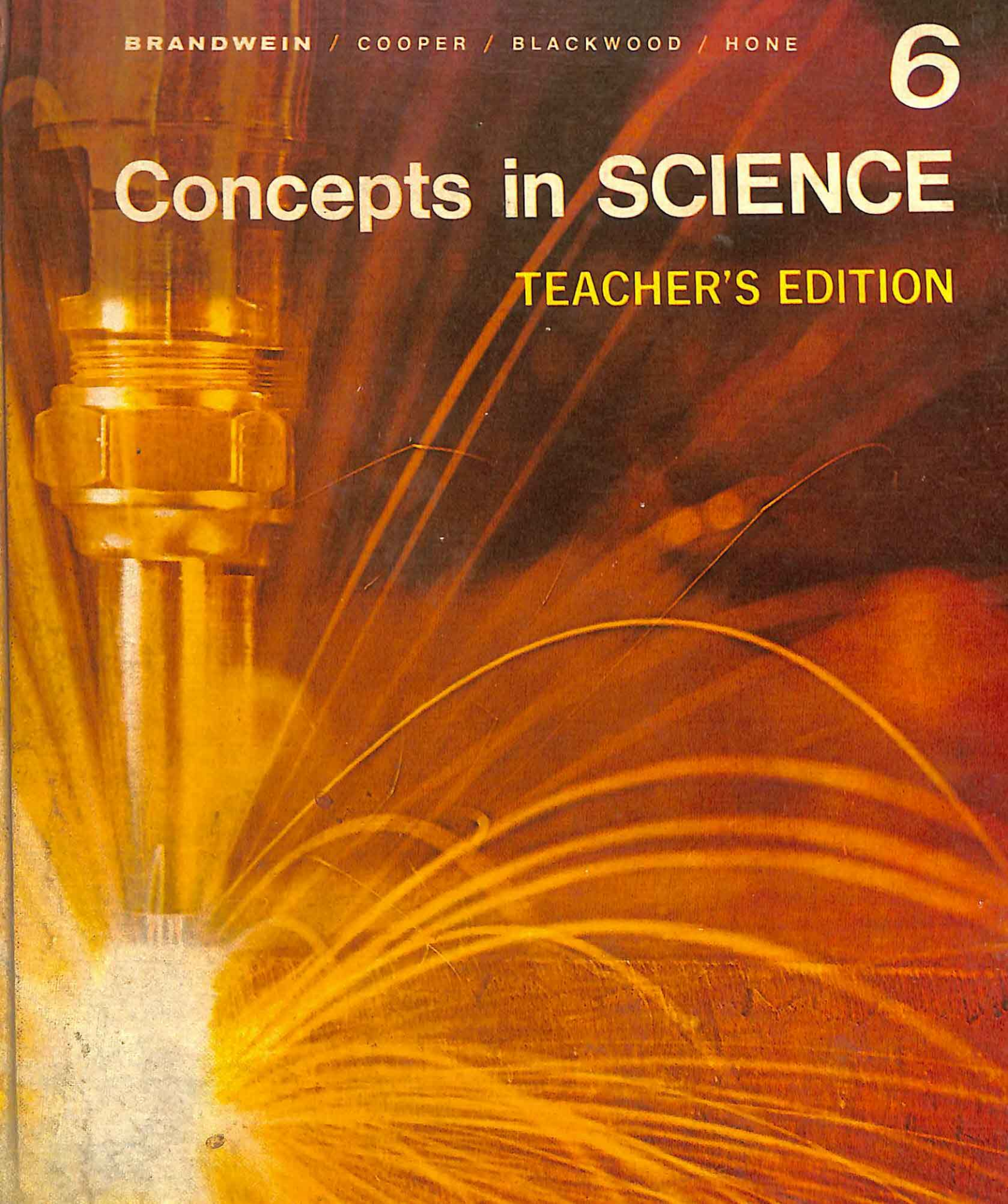


BRANDWEIN / COOPER / BLACKWOOD / HONE

6

Concepts in SCIENCE

TEACHER'S EDITION



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CONTENTS

Part One: CONCEPTS IN SCIENCE Series

The Teaching of Science	F-7
A Modern Science Curriculum	F-9
A Comprehensive Program	F-12
A Structure for Concepts in Science	F-14
Resources for a Comprehensive Program	F-16

Part Two: CONCEPTS IN SCIENCE 6

Structure and Content	F-19
Useful Teacher References	F-23
Addresses of Publishers	F-25
Addresses of Audiovisual Suppliers	F-26
Answer Key to TEACHING TESTS	F-26

TEACHING SUGGESTIONS

UNIT ONE LEARNED AND UNLEARNED BEHAVIOR	T-1
UNIT TWO IDEAS AND TOOLS: FOR NEW PRODUCTS	T-20
UNIT THREE IDEAS AND TOOLS: FOR LONGER LIFE	T-40
A CONCEPT OF INTERDEPENDENCE: A NEW VIEW	T-69
UNIT FOUR MACHINES IN ACTION	T-72
UNIT FIVE MOLECULES IN ACTION	T-92
UNIT SIX ELECTRONS IN ACTION	T-110
UNIT SEVEN MATTER INTO ENERGY	T-132
A CONCEPT OF MASS-ENERGY: A NEW VIEW	T-149
UNIT EIGHT CODE OF HEREDITY	T-152
UNIT NINE STARS AND STARLIGHT	T-176
A CONCEPT OF CHANGE: A NEW VIEW	T-195
ON YOUR OWN: THE ART OF INVESTIGATION	T-198
KEY CONCEPT WORDS: A BEGINNING VOCABULARY FOR SCIENCE	422
INDEX	430

The Investigations in CONCEPTS IN SCIENCE 6

The pupil's textbook contains 54 investigations which are integral to the building up of basic concepts in science. Some of these investigations can be performed with the use of readily available materials. Others require simple equipment or materials that normally are less easy to obtain. *Classroom Laboratory 6*, described fully on pages

F-17-18, supplies in conveniently packaged form much equipment and materials not usually available locally. A listing of the investigations follows, with the page number of the pupil's textbook and a symbol which indicates that one or more items for the investigation are available in the *Classroom Laboratory*.

UNIT ONE

LEARNED AND UNLEARNED BEHAVIOR

* Things You Can Do from Birth	5
A Common Reflex	13
The Training of a Fish	19
* The Learning of an Automatic Act	25
* A "Problem" in Learning	29
How Regular Practice Fixes a Simple Habit	33

UNIT TWO

IDEAS AND TOOLS: FOR NEW PRODUCTS

* What Happens When an Electric Current Is Passed Through Copper Sulfate	50
* The Motion of Molecules	58
The Nature of Heat	59
* Getting a Metal from Its Compound	72
How Fast a Tin Can Rusts	81

UNIT THREE

IDEAS AND TOOLS: FOR LONGER LIFE

* Growing Bacteria	101
* How Fungus Plants Get Their Food	105
* The Use of Diastase	106
* What Happens to Bacteria in the Stomach	112
* How to Keep Bacteria from Growing	115
Purifying Water with Chemicals	134
Keeping Water and Food Free from Bacteria	137

UNIT FOUR MACHINES IN ACTION

* An Inclined Plane as a Simple Machine	155
* Another Simple Machine, a Lever	157
* The Location of the Fulcrum	162
* The Use of a Pulley	167
* Using a Block and Tackle	169
* A Winding Inclined Plane	173
* The Force of Friction	181
* How a Simple Machine Multiplies Force	185

UNIT FIVE MOLECULES IN ACTION

* How an Expanding Liquid Can Do Work	199
* What Happens When a Fuel Burns	207
* A Mysterious Push	213
Flight from Da Vinci to Goddard	215

UNIT SIX ELECTRONS IN ACTION

A Force of Attraction	233
Lighting a Bulb with an Electric Current	237
* An Electric Current	239
* The Flow of Electrons	241
The Similarity of Electric Bells and Motors	249
Making a Model: An Electric Bell	250
Making a Model: An Electric Motor	255
Making a Model: A Telegraph	259
* Making a Model: A Simple Telephone	263
A Modern Telephone	265
* A Force from a Wire	269

UNIT SEVEN MATTER INTO ENERGY

* Models of Atoms	289
* Making Models: The Atom	293
The Detection of Radioactivity	300
Making a Model: A Nuclear Reactor	306

UNIT EIGHT CODE OF HEREDITY

* The Effect of Environment on Living Things	327
Cross-Pollination of Petunias	338
Grafting	349
* The Kinds of Fruit Flies You Can Find	351

UNIT NINE STARS AND STARLIGHT

A Chemical Combination of Hydrogen	367
* Heat and Temperature	375
Measuring Things That Are Very Distant	377
* A Way of Counting Very Large Numbers	382
Compression of Gases	389



Part One: CONCEPTS IN SCIENCE Series

The Teaching of Science

A class of sixth-grade pupils was making a tour of the school grounds with their teacher to note the kinds of machines being used in the construction of an addition to the school. With enthusiasm they commented on the cranes, derricks, and bulldozers that were moving earth and construction materials around. As they stopped near some heavy planks and a pile of building stone, the teacher said, "I can invent a machine with these materials so that the smallest one of you can easily lift two of the heaviest." Some of the pupils grinned with disbelief; others were more vocal. Two or three, proud and impatient with knowledge, offered the solution, "You're going to make a lever." But still there was skepticism. The teacher selected a stone, arranged one of the heavy boards over it, asked two of the larger pupils to stand on the end that was nearest the stone, and then selected one of the more vocal disbelievers to lift the two pupils. Of course, the invention worked. The lever multiplied the force of the smaller pupil, as many machines do.

How do machines work? The pupils returned to the classroom, which was now a laboratory. There, during the course of a number of days, they made models of different kinds of machines, investigated how they multiplied force or changed the direction in which the force was applied or increased speed. They invented variations on machines that would multiply the force of muscles and they combined them. They performed mathematical calculations and arrived at certain relationships. At one point, the teacher connected a coil of wire to a dry cell, inserted an iron spike, and picked up a pile of steel tacks. From there the class proceeded to study how inventive persons who understood concepts of science found ways to substitute other sources of energy for man's muscles. During all these investigations the pupils tested their understanding. They collected and recorded data. They used books to check their observations. They interpreted their data and exchanged views of their interpretations.

They were, in short, engaged in the processes of science. They were also engaged, as we shall see, in the process of concept-seeking and concept-forming. And they were also using their minds to invent ways to use concepts in doing the world's work.

Now, none of what was done in this school yard and classroom will seem unusual to the imaginative teacher. What is of consequence to teachers and curriculum makers (and writers) is that such experiences should not become merely isolated parts of teaching science, that indeed, in the teaching of science, there should be a structure that is sound in itself. What the teacher was doing with the lever in the school yard and in the classroom was to use technology (in this instance, a lever and fulcrum) to create a situation through which children discovered concepts of science. We prefer to say that a good teaching program *uncovers* the concepts of science. Piaget's classical statement on this subject amounts, eventually, to this: the teacher creates situations through which children discover structure. By "structure" he meant relationships or likenesses among objects and events. A concept is a grouping of relationships, of likenesses, which explains objects and events in the world about us. Each of us tends to uncover the relationship at some particular time, but of course the relationship had been operating in the world before we came on the scene. A concept is new only to scientists, or to us, or to the children. The teacher's art lies precisely in the creating of situations through which children uncover concepts. This appears to be a plain and clear prescription, but of course there are some extremely complex problems confronting the teacher.

There is, obviously, the weight of the teacher's responsibility in teaching science today. In the second half of the twentieth century, children are born in a science-oriented world, in a culture that puts an extraordinary premium on scientific thought

and on scientific production. It is sensible to predict that most jobs in the future, including that of teaching, will call for scientific orientation of one degree or another. Contemporary-minded teachers must teach science because society demands it. Helping children to undertake a progressively more sophisticated intellectual activity is a central function in teaching, and creating productive situations—that is, the learning environment—is the teacher's day-to-day responsibility. It is, in many respects, an awesome one. Which situations—of all the countless ones that might be created—is the teacher to select? How is she to cope with the incredible diversity of scientific information, and indeed, with the diversity of children themselves?

From the time children are born, they watch, smell, feel, and listen: they are sentient to the objects and processes of the world. What they know largely derives from their senses and from their perceptions and from the number and kinds of experiences they have had. They acquire meaning, whether true or false, from many kinds of experience—in the classroom, in backyard play, in the streets, in the kitchen, in solitary reflection. They ask questions and examine things and ask still more questions. Because among individuals sensory perception varies and because human experiences vary in both kind and number, no two children begin school with the same knowledge, or with the same set of experiences. It cannot be presumed, therefore, that within the school framework they will move with equal speed or along precisely similar lines of growth. Some kind of provision has to be made to accommodate children of varying experience and of varying ability, and that provision is not alone concerned with the broader questions of homogeneous grouping in schools or of an ungraded curriculum; it is also concerned with providing a scientifically sound structure of learning and teaching science that enables children to uncover the concepts of science in an orderly (though not overly prescriptive) way and at a pace of their individual competency.

A structure in the teaching of science is needed not only to accommodate the phenomenon of diversity in children but also to manage the diversity of the content of science. Scientific research papers are currently being published at the rate of 67,000 words a minute! That amounts to a body of information that would fill eleven sets of a thirty-volume

encyclopedia every twenty-four hours. Quite obviously, unless an attempt is made to evaluate, to select, and to sort new information into some kind of structure for the classroom, teachers will fall further and further behind. There is, moreover, the necessity to recognize that scientific knowledge, while it proceeds from facts, is not in itself the mastery of facts. Facts become meaningful, and the awareness of facts ultimately becomes productive, when they are perceived within the structure of basic concepts. We may modify George Gaylord Simpson's definition of science slightly. *Science is the exploration of the material universe for the purpose of seeking orderly explanations of objects and events, explanations that must be testable.* The products of science—which are its orderly explanations and the technology that results from the particular application of them—are the results of certain processes. The processes comprise, first, the observation and examination of data, including experimentation; second, the formulation of explanations by means of inventing hypotheses and stating theories; and third, the testing of the explanations. But the product of all this, the explanations, leads inevitably to other explorations and still other explanations. There are ends in science, but there is no end to science itself.

In their activity, scientists engage in concept-seeking and in concept-forming, and as a matter of course, in concept-testing. This is clearly a function of scientific inquiry. But what do children do when they are engaged in scientific activity? They explore the material universe (observe a plant grow, observe an object move down an inclined plane, observe a balloon that has been untied shoot through the air) and they seek orderly explanations of the objects and events they observe. They also investigate, and where possible, they might even experiment (although in a school context it is most difficult for students to perform an experiment in the *pure* sense simply because all the variables are difficult to control). They verify the data obtained from observations and they seek to interpret the data. They seek to predict results on the basis of the knowledge they have gained. They attempt to uncover explanations that reliably relate seemingly disparate or "discrepant" objects and events, and that will make prediction of other events possible. They are engaged in understanding concepts of science and in applying them to the world about them.

Identifying the basic concepts of science is not the discrete task of the teacher. The teacher has the right to expect that she will be given help in identifying concepts and in forming a structure for the teaching of science, and this is a shared responsibility that the *Concepts in Science* authors and publisher, and the scientists and teachers who have advised them, have accepted. They recognize that school is time-binding, that work goes on in a certain time span—grades, terms, years—and that many teachers share in the development of each child. They know that a teacher must have a notion of what school experiences children have had before they come into her ken, as well as what will

follow once they leave her. The need for a curriculum in science which gives the teacher scope and flexibility is plain enough; what is sometimes not so plain is the need for a curriculum that has a scientifically sound and pedagogically sound structure. We have attempted to give structure to the teaching of science during the first nine years of schooling by informing the processes of science with an understanding of the concepts. We have, in short, sought to identify and define a structure that is not only verifiable scientifically but also viable (practical, productive) in teaching. The conceptual approach is central, in our view, to both aims, both to sound science and sound teaching.

A Modern Science Curriculum

Early in the twentieth century the school curriculum in the United States tended to be content-centered, or disciplinary. During the twenties and thirties this curricular approach gave way to a so-called child-centered approach; the emphasis was shifted—this is overstated for purposes of simplification—from the subject to the learner. Today, still another shift is occurring as content is being placed in a stronger and more relevant role in the curriculum. More and more the emphasis is placed on the interrelationship, more specifically the interaction, between the discipline and the pupil in the learning act. Again with some oversimplification, the contemporary curriculum can be said to be process-centered. Certainly this is apparent in science teaching, and the advance of this kind of curriculum has been most directly aided by the involvement of scientists in the elementary and secondary schools. They have been enormously helpful in proposing a teaching structure for the early school years of science study.

Within the various disciplines of science—biology, chemistry, physics, geology, etc.—data accumulate and change at a bewildering rate. Change is constant. Yet the concepts of science—which are a patterning of facts and a statement of the relationships between observable events and objects—are relatively stable. In a changing world, concepts offer, for this and other reasons, a reasonable foundation for the building of a science cur-

riculum. They are, in a true sense, guides as well as aids to learning.

All of us have the task of sorting out events that come to our awareness in haphazard sequence. All of us have the task of discovering which of the objects and events we perceive are significant and which are not. To bring order out of our haphazard perceptions, we tend to seek a grouping of likenesses among a number of objects and events perceived; in short, we tend to seek concepts. To form a concept, we assort or group objects and events according to their attributes and properties, and we define categories. An example of what is meant by the “attributes” of an object or event will be useful.

A stone has shape, color, weight, and the like; these are some of the attributes of a stone. A bird also has shape, color, weight. Yet there are other attributes of the stone—for example, immobility and hardness, which we recognize as part and parcel of “stoneness.” A bird, on the other hand, has mobility, it has feathers, it has egg-laying propensities, and it has a certain structure (from beak to tail)—these and other attributes we recognize as essential to “birdness.” In forming a concept, the brain selects those essential attributes (those which discriminate one object from another) which signal the whole configuration of the object or event. Thus the weight of an object is generally not an essential or discriminatory attribute; an attribute of a weight of one pound might apply to a one-pound chicken

or a one-pound stone. But "feather" or "beak" is a signal, or cue, for categorizing or concept-forming. It is a signal of the whole concept of "birdness" and it enables us to fill in certain other essential attributes.

Now in learning, the *act of concept-forming* enables an individual to infer; from a few signals or cues he can infer a significant grouping, or category, of like attributes. These signs or cues can be related to *objects* (stones, birds, simple machines) or to *events*, such as the changing of one form of energy to another (for example, the friction of the hands resulting in heat, or the reproduction of organisms, or the splitting of an atom). A specific example in the teaching of a concept, in developing the ability in children to group the like attributes of an event, can be given here. Suppose we wished to create situations through which children would uncover the events that can be grouped within the concept: *The amount of energy gotten out of a machine does not exceed the energy put into it.* This is precisely the objective of Units Four to Six in *Concepts in Science 6*. A series of lessons is organized in a sequence in which situations are created whereby children come to *associate* an entire set of attributes of this concept: *The amount of energy gotten out of a machine does not exceed the energy put into it.* Even if pupils were to perform only the 23 investigations in these three units, they would be selecting attributes of machines. This would enable them, in turn, to predict a transfer of energy from one signal, say, water turning a turbine. But the text suggests activity after activity—multiplying force with a lever, changing its direction with a pulley, increasing speed with a wheel and axle, using the kinetic energy of molecules, and generating electric current. All these are observed and analyzed. Perhaps you would care to examine one of these units now for a fuller explanation of the way the text assists the teacher in creating situations through which children engage in concept-seeking and concept-formation. But, of course, the text is only part of a very rich program of science in which process is central (see pages F-16—18).

In brief definition, then, *a concept is a mental construct; it is a grouping of the common elements or attitudes shared by certain objects and events.* Once a concept is attained, economy in future learning is also attained. For by engaging in the processes of concept-formation, the learner is active

in selecting the essential attributes of the complete event, such as "the amount of energy gotten out of a machine does not exceed the energy put into it." And the learner is able to predict an entire sequence of events, or an entire set of characteristics or properties, from a small number of cues or signs. Thus an increase in heat or the ringing of an electric bell in a circuit is a cue signaling an entire event.

Defined in other words, a concept is a network of inferences stemming from observation of objects and events, resulting in the selection of common attributes among the objects and events under observation. Identifying and organizing the common attributes results in a significant category or grouping. That significant category is a concept. A concept is practical and useful because the perception of a small number of attributes, cues, or signals brings the whole object or event into satisfying recognition. To repeat, an increase in heat brings to mind the object (the molecules in motion) and the event (the release of kinetic energy).

Because we are teaching children, it is well to group experiences in a way which will enable teachers to plan their work sequentially. Hence we have ordered the *concept structure of the curriculum you have in hand*. It provides for small blocks of experiences, dealing with objects and events with similar attributes which young children can handle. We have attempted, moreover, to develop a curricular structure which bears some correspondence to the school year, day, and period. Further, for purposes of readier facility in planning the work of the first six years of elementary school, we have grouped a given series of concepts under a still larger category which we call a *conceptual scheme*.

Conceptual schemes provide, we believe, a framework within which the teacher can provide experiences that will lead students to participate in the processes of science—in observation and in interpretation—and emerge with the products of science, which are testable explanations of the workings of the material world. This seems to be a large order. It is. The authors and publisher have spent eight years in the preparation of the curricular organization and materials in this program. They have tested their performance during hundreds of hours in typical classrooms. It is their belief that the conceptual approach is a feasible one that will

produce excellent results. In an ultimate sense, their aim is to help the teacher produce an interaction between discipline and student, between the subject and the learner. For this reason, content is never skimmed. For each grade there is a hard core of content or subject matter that exceeds more than even the bright child will be able to encompass in the time he is generally allowed.

What has been done in this program, then, is to lay out a framework of conceptual schemes through the first six years of schooling. The framework is capacious. It does not fix the teacher or the student into an inflexible curriculum. On the contrary, it gives the teacher freedom to plan a variety of experiences and it gives the student freedom to plot his own experiences. In both instances, however, the experiences will be ones which are relevant to a search for meaning rather than for the random acquisition of facts. In a real sense, understanding is made simpler for children when they are able to conceptualize—to see patterns in their environment, to group objects and events on the basis of their common elements. A program that accomplishes this is essentially an economical one, economical in the time that is spent in learning. Because, as has been said earlier, concepts remain relatively stable, concepts provide an organization of information that is relatively stable. New observations, new data, variant experiences can all be fitted into the conceptual framework.^o

Teachers in St. Mary's County, Maryland, have been experimenting successfully with an elementary science curriculum based on conceptual schemes. Their course of study, initially developed by a curriculum committee, is now in its sixth year of development. Similar courses of study have been developed by other schools and school systems, particularly the Nova School, Fort Lauderdale, Florida.

If we interpret the psychology of learning (so far as it has advanced, which admittedly is not far enough!) with any degree of acuity, then we assume that it is important for children to learn in "wholes." In this sense, concepts are "wholes." Moreover, if we accept the definition that education should re-

sult in a change of behavior in the student, then an understanding of concepts will provide a person with intelligent means of deciding among alternatives. The conservation of natural resources; the support of public health programs; the questions of population growth; the fallacies in ethnic discrimination—all these are civic and social matters that confront a contemporary person. He is better able to judge what he perceives, and better able to support what he believes, when he understands the basic scientific concepts. The teaching of science ought to do more than dispel ignorance and superstition; it ought to help provide means by which a human being can comprehend what is today known but still unseen or still not widely operative. Exploration of the moon is a certainty, even though it has not yet happened.

The *Concepts in Science* series is an elementary science curriculum which attempts to reflect commonly accepted and basic ideas of contemporary scientists, cognitive psychologists, and teachers. It is a systematic organization of instructional materials. It is also a laboratory-centered program. The framework of six conceptual schemes provides a learning sequence that is shown, in broad outline, on the chart on pages F-14 and F-15. The sequential development is represented on the chart as horizontal threads called *concept levels*, which increase in complexity as one advances from one level to the next.

The National Science Teachers Association Committee on curriculum development, in "Theory in Action,"^o suggests seven conceptual schemes. The Committee agrees upon twelve statements. Seven of these statements discuss conceptual schemes, and five of them describe the process of science as the base for science curriculum planning. In the *Concepts in Science* series, the concepts have been grouped under six conceptual schemes, but the differences between this organization and that of "Theory in Action" is not substantial or finally consequential. The authors suggest that the content of the science curriculum could be arranged in an orderly structure under six conceptual schemes in a way that effects economy in organization, time, and effort.

^o See *A Study of Thinking* by Jerome S. Bruner, Jacqueline J. Goodnow, George A. Austin, John Wiley & Sons, Inc., New York, 1956.

^o Published by the National Science Teachers Association, 1964.

The major conceptual schemes can be stated in somewhat arbitrary terms; no doubt, different teachers will state them differently. Certainly they would be stated differently for the scientist-specialist than for the elementary-school teacher, who of necessity teaches not only science but English and social studies. Certainly the statements may be modified and restated under different conditions, with different pupils and in different schools. Yet the authors have chosen to state the conceptual schemes in terms that can be used throughout the particular content and activities in the *Concepts in Science* series.

A Framework of Conceptual Schemes

The conceptual schemes and the general areas they subtend are:

1. When energy changes from one form to another, the total amount of energy remains unchanged.

Energy transformation is a common phenomenon. If you rub your hands, mechanical energy is converted to heat energy. If you burn a candle, chemical energy is converted to heat and light; and in a dry cell, chemical energy can be converted to electric energy. But whether one is concerned with burning oil in the home, gasoline in the automobile, glucose in the body, or whether one is concerned with the transfer of the energy of moving water into a flow of electrons in a conductor, the total amount of energy in any given system remains unchanged. This conceptual scheme is a primary concern in the discipline of physics.

2. When matter changes from one form to another, the total amount of matter remains unchanged.

The world of matter consists of a world of things, from the very large bodies—stars, planets, moons, and other celestial bodies—to the very small particles—atoms, molecules, and subatomic particles. As the matter in the universe undergoes physical change, a change of state, and chemical change, a change in form, the total amount of matter undergoing chemical or physical change in any given system remains unchanged. This conceptual scheme lies within the discipline of chemistry.

3. Living things are interdependent with one another and with their environment.

Around living things everywhere, there exists an environment of matter and energy; indeed, living things cannot be considered apart from their environment. Plants depend upon their environment for their growth and development. Green plants capture energy from the Sun in the photosynthetic process; animals, in turn, transform the chemical energy of plants. And finally, all plants and animals yield their matter and energy as they die and decay. In addition, the demands of living in a given environment result in a relationship between plants and animals in communities that display definite characteristics—deserts, forests, seas, ponds, etc. For example, the sea is an environment in which ninety percent of the world's photosynthesis takes place, where complex food niches are developed, and intricate reproductive cycles operate. Understanding these interrelationships results in our ability to predict, within limits, the behavior and development of plants and animals. The conceptual scheme that describes them is a part of the study of biology.

4. A living thing is the product of its heredity and environment.

Within this conceptual scheme, one can develop the concept of an organism that lives in a kind of dynamic equilibrium. The organism is never the result purely of its heredity but of the environment interacting with hereditary factors. This is true of any specific trait. This is also important to comprehend in a human being's realization of full physical development and vigorous health. Other examples:

A red barberry is greenish unless exposed to strong sunlight.

An intelligent child needs an education.

Beets in acid soil are stunted.

A child lacking vitamin B may develop beriberi.

A potato seedling in the dark is attenuated.

A child poorly fed and poorly housed does not resist tuberculosis as well as one who lives in a more salutary environment.

The full range of the development of organisms—including the study of reproduction, genetics, growth, nutrition, behavior, and adaptation to the

environment—is involved in this conceptual scheme, which is the concern of several sciences: genetics, physiology, and biochemistry.

5. Living things are in constant change.

The universe changes; the Earth changes; the single organism and the species change over the ages. The concepts of adaptation over the ages, divergence in form, convergence in geographical isolation, and evolution are within the purview of this conceptual scheme, which involves genetics and ecology.

6. The universe is in constant change.

Every child today seems to know that the solar system is changing. Certainly the earth's atmosphere is constantly shifting. The Earth is in constant motion; the Sun is in constant eruption. We note the appearance of novas and supernovas. We observe and gain evidence from Cepheid variables. We interpret the red shift in starlight to indicate an expanding universe in constant change. The change in the universe comprises a conceptual scheme that is the primary concern of geology, astronomy, and meteorology.

A Developmental Structure of Concepts. Expectedly, as the concepts in science are selected to fit the purposes of instruction in the elementary school, they seem to group themselves easily. The rationale is this: first, concepts should fall easily into a particular conceptual scheme; second, they should be ordered from the simple to the complex. "Simple" is used here in the sense that the experiences provided should be simple. Young children do not deal with a complexity of cause and effect, that is, with *multiple variables*. For example, it is fairly easy in the second grade or level to deal with the concept *related living things reproduce in similar ways*. On the other hand, the concept *the characteristics of a living thing are laid down in a genetic code* requires that we make available more complex experiences which are appropriate at higher levels. All this is not to imply that some children cannot deal with more complex structures even while the norm for a class is said to be a concept development at a lower level. A particular advantage of a conceptual structure in the curriculum is the provision for extended or

accelerated growth in individual children. For instance, if a child seems to understand a concept at a higher level of complexity than his classmates, the teacher can determine the level of understanding by asking appropriate questions at a lower concept level (pages F-14—15). If a sufficient number of children are able to deal with a higher concept level, procedures may then be modified.

The organization of a curriculum in terms of concept levels accommodates its own "multiple tracking." As a result, it is possible to have groups, or even individuals within the same class, proceed at different rates up the concept "rungs" of the conceptual "ladder." They can engage in experiences which are appropriate to their level of understanding, and at the same time communicate with groups at other concept levels. In other words, they are all on the same ladder, if on different rungs. In any event, a teacher will certainly wish to know the entire conceptual structure. The structure for *Concepts in Science 1-6* is charted on pages F-14—15.

The concepts which form the rungs of the conceptual ladder can be stated in various ways, but the central purpose is to organize them in graduated order so that understanding of one (in a lower level) precedes the next for purposes of greater comprehension and utilization. There is some danger, we believe, in stating a conceptual scheme (or even a concept) by a single term (for example, *energy, matter, life*). However convenient this may seem, such easy rubrics may have the effect of limiting the implications of this approach to science study.

Now, the structure for science in the first six grades of the elementary school, here given as six conceptual schemes, with the concepts given at six levels (not necessarily grades), is purely for convenience and custom. The levels, until research proves this unwise, are in a rough order of precedence. Naturally, each concept has a number of subconcepts; the development of subconcepts depends on the judgment of the teacher.

The essence of science is *investigation of the material universe*. Its goals consist of a search for meaning; indeed Albert Einstein once defined it as experience in search of meaning; it *seeks orderly explanations (conceptualizations) of phenomena, the objects and events about us*. Nevertheless, there is stubborn insistence by scientists that an orderly explanation *be testable*. If a concept is not testable, it is usually not acceptable. Science is, in

	CONCEPTUAL SCHEME A When energy changes from one form to another, the total amount of energy remains unchanged.	CONCEPTUAL SCHEME B When matter changes from one form to another, the total amount of matter remains unchanged.	CONCEPTUAL SCHEME C Living things are interdependent with one another and with their environment.
CONCEPT LEVEL VI	The amount of energy gotten out of a machine does not exceed the energy put into it.	In nuclear reactions, a loss of matter is a gain in energy; the sum of the matter and energy remains constant.	Living things are adapted by structure and function to their environment.
CONCEPT LEVEL V	Energy must be applied to produce an unbalanced force, resulting in motion or change of motion.	In chemical or physical changes, the total amount of matter remains unchanged.	The capture of radiant energy by green plants is basic to the growth and maintenance of all living things.
CONCEPT LEVEL IV	A loss or gain of energy affects molecular motion.	In chemical change, atoms react to produce change in the molecules.	Living things capture matter from the environment and return it to the environment.
CONCEPT LEVEL III	The Sun is the Earth's chief source of radiant energy.	Matter consists of atoms and molecules.	There are characteristic environments, each with their characteristic life.
CONCEPT LEVEL II	Energy can change from one form to another.	A change in the state of matter is determined by molecular motion.	Living things depend on their environment for the conditions of life.
CONCEPT LEVEL I	Energy must be used to set an object in motion. There are many forms of energy.	Matter commonly exists as solids, liquids, and gases.	Living things are affected by their environment.
	CONCEPTUAL SCHEME A When energy changes from one form to another, the total amount of energy remains unchanged.	CONCEPTUAL SCHEME B When matter changes from one form to another, the total amount of matter remains unchanged.	CONCEPTUAL SCHEME C Living things are interdependent with one another and with their environment.

CONCEPTS IN SCIENCE

CONCEPTUAL SCHEME D A living thing is the product of its heredity and environment.	CONCEPTUAL SCHEME E Living things are in constant change.	CONCEPTUAL SCHEME F The universe is in constant change.	
The characteristics of a living thing are laid down in a genetic code.	Changes in the genetic code produce changes in living things.	Nuclear reactions produce the radiant energy of stars, and consequent change.	CONCEPT LEVEL VI
The cell is the unit of structure and function; a living thing develops from a single cell.	Living things have changed over the ages.	Bodies in space (as well as their matter and energy) are in constant change.	CONCEPT LEVEL V
A living thing reproduces itself and develops in a given environment.	The environment is in constant change.	The motion and path of celestial bodies are predictable.	CONCEPT LEVEL IV
Living things are related through possession of common structure.	Living things grow and develop in different environments.	There are seasonal and annual changes within the solar system.	CONCEPT LEVEL III
Related living things reproduce in similar ways.	Forms of living things have become extinct.	There are regular movements of the Earth and Moon.	CONCEPT LEVEL II
Living things reproduce.	There are different forms of living things.	There are daily changes on Earth.	CONCEPT LEVEL I
CONCEPTUAL SCHEME D A living thing is the product of its heredity and environment.	CONCEPTUAL SCHEME E Living things are in constant change.	CONCEPTUAL SCHEME F The universe is in constant change.	

short, the "art of investigation" (Beveridge's term). But one cannot investigate an object or event if the object or event is not first perceived.

This book is literally a sourcebook of situations in which children participate and perceive objects and events. In creating a learning situation, children are given opportunity to seek the attributes of objects and events and to seek hidden likenesses. In the situation described on page F-7, the sixth-grade children engaged in these processes: they *observed* the working of a lever; they *investigated* the relationship between machines and forces; they

collected relevant data; they *described* the operation of the lever and other simple machines; they *discussed* their results; they *confirmed* one another's results (through collaborating in an investigation); they *read* the work of scientists; they *invented* and then *reported* their results in a kind of colloquium. Note the processes: observation, investigation, collection of relevant data, description of results, discussion of findings, confirmation of findings, reading the work of scientists, exercising inventiveness, reporting of work, and within limits, experimentation, among other processes.

RESOURCES FOR A COMPREHENSIVE PROGRAM

The structure of science and the processes of science yield knowledge and they yield understanding but at no time could they exist without the materials of science—materials which provide the media for investigation, whether the investigation involves reading a textbook or carrying out a sophisticated experiment in the laboratory. The materials for *Concepts in Science* include the facts of science as well as the tools of science. These materials come in the form of reading matter, illustrations, manipulative objects, laboratory guides, testing instruments, and other aids to teaching.

The *Concepts in Science* series provides the whole range of suitable materials for Grades 1-9. It includes basic textbooks for the child, each accompanied by a Teacher's Edition for Grades 1-6 (a separate Teacher's Manual for Grades 7-9); Workbooks for Grades 4-9; packaged equipment for Grades 1-6 called *Classroom Laboratory*; individual investigation cards called *100 Invitations to Investigate*; and *Teaching Tests*. There are, moreover, books available for the teacher.

TEXTBOOKS

Each book in the *Concepts in Science* series is organized to accomplish efficiency in the learning process. Each book is designed to create an atmosphere of discovery in concept development; to stimulate personal involvement; to maintain sharp curiosity; and to lay a firm basis for intelligent action and independent inquiry. The processes of science, as well as its products, are emphasized

and yet interrelated as the pupil participates in the act of learning. Each book is illustrated for visual interpretation of objects and events that may or may not be a part of the pupil's everyday experience.

While the full-color photographs and drawings enhance the visual quality of the textbooks, they serve the important function throughout the program of training children to observe with discrimination the pictorial representations of their physical environment. Many of the photographs are of actual performances by pupils and experienced teachers in the classroom.

Each book contains an abundance of investigations to help develop the main concept of a section. As the investigations are self-contained and self-explanatory, except in *Concepts in Science 1* and *2* where the directions are given by the teacher, little discussion of the investigations is given other than to suggest possible pitfalls and to advise on the most profitable time during the lesson to undertake the investigation. Actual photographs illustrate one trial investigation. Since the text does not tell what happens, the photographs serve as guides for the pupil; but the pupil must observe for himself and try the investigation. All investigations have been laboratory tested for effectiveness and safety.

In addition to the investigations that are found at strategic points within the sections, there are "open-ended" investigations at the ends of the sections as well as at the ends of the units. Each investigation is an extension and addition to the pupils' initial concept formation. Furthermore,

these additional investigations point up the fact that many trials are necessary to establish and confirm results of one investigation. End-of-book sections, which progress in difficulty from book to book, stimulate individual investigation that is relatively complex in observation and experience.

Each book in the *Concepts in Science* series features cumulative concept reviews and evaluations which enable the pupils to test their understanding of a concept. These reviews enable pupils, moreover, to apply their understanding to new situations, to hypothesize solutions to a variety of problems, to recognize relationships among concepts, and to infer relationships among conceptual schemes. At every step of the way the pupils are provided with experiences which help them find unity among diversity, to achieve order out of disorder in the objects and events of the world around them.

Concepts in Science builds a precise science vocabulary. Throughout the program, provision is made for growth in vocabulary as it specifically relates to science. In *Concepts in Science 1* and *2*, the teacher is encouraged to introduce new words on a science vocabulary chart to be displayed in the classroom. These same words are listed in the back of the child's text for his individual use. In *Concepts in Science 3-6*, key words are introduced in boldface type and repeated, with page references, in the glossary. Definitions increase in depth and extension of meaning from book to book.

The reading vocabulary has been carefully controlled for the grade level throughout the program, with due attention to the adequate presentation of technical vocabulary necessary to understanding concepts in science. In *Concepts in Science 3* and *4*, a pronunciation-at-sight system is used; and in *Concepts in Science 5* and *6*, a standard system of diacritical marking is used.

TEACHER'S EDITIONS

The Teacher's Editions to accompany the *Concepts in Science* textbooks are organized for maximum teaching effectiveness. They contain the background information that teachers need to teach a unit with confidence and enthusiasm which eliminates, for the most part, the necessity for further research on the part of the teacher. The conceptual structure of the curriculum is outlined clearly, and carefully selected activities and ex-

periences are prescribed and described as effective means of concept development.

A comprehensive teaching pattern is apparent in each of the teacher's editions and is analyzed in detail in **Part Two** of the introductory material in each book. For this book, see pages F-19-23.

CLASSROOM LABORATORY

The classroom for science should resemble a laboratory in which children actively work with objects at their own desks or tables, individually and in groups, observing, rearranging, manipulating, investigating, experimenting, testing, and discussing findings and inferences with one another.

The *Classroom Laboratory* for the *Concepts in Science* series is a practical way of converting an ordinary classroom into a classroom laboratory. There is one each for *Concepts in Science 1-6* which is designed to fit the needs of the science curriculum by providing the materials and equipment for pupils to experience science in the classroom. It is built around the concepts of the science curriculum; it anticipates and solves the problems of classroom management, and is designed to be used by the entire class.

While an entirely optional part of the *Concepts in Science* program, the *Classroom Laboratory* deals with investigations that give pupils the opportunity to uncover the science concepts that are developed in the basic textbooks. Part II of the Teacher's Manual which accompanies the *Classroom Laboratory* is keyed by page number to the pupil's textbook. Similarly, the Teacher's Editions are keyed to the *Classroom Laboratory* so that a teacher will know at once if materials are provided for an investigation in *Concepts in Science 1-6*. Part III of the Teacher's Manual for each *Classroom Laboratory* provides for additional investigations that enrich the child's experiences.

Each *Classroom Laboratory* is accompanied by a Teacher's and Pupil's Instruction Manual.

To provide opportunities for an entire class to experience the processes of science, the equipment and materials are supplied in multiples of six, except in the case of certain types of equipment for which one item is adequate for the experience of all the children. A class of 30 pupils, for example, may be divided into six groups of five pupils, with each group performing the same investigation. There are also materials for the performance of

numerous individual activities which may be used as teacher or committee demonstrations. Furthermore, the laboratory is so organized that it is possible to find any required material within a few moments and to return it easily to its proper place for future use. Many items are also useful for the activities in the workbooks, described below.

While the contents of the individual laboratories differ, depending on grade level, each one contains a tray of commonly-used apparatus: beakers, test tubes, tripods, plastic tumblers, plastic dishes, and other basic materials which can be reused whenever needed. With normal use, some depletion of parts will occur each year and a small portion of the items are consumable. Replacements are available from the publisher.

WORKBOOKS

Concepts in Science Workbooks, available for Grades 4 through 6, give pupils additional opportunity to reinforce and extend their understanding of the concepts developed in the *Concepts in Science* textbooks. Through the experiences that are provided in these workbooks, pupils review concepts and apply them in new context. New problems are introduced which are related to problems they have already studied, but which differ in some significant way from those in the textbooks. Moreover, the workbooks give additional practice in utilizing basic laboratory skills—recording observations, tabulating data, interpreting data, and drawing conclusions—as well as practice in using scientific apparatus. The activities in the workbooks have been selected to provide experiences in various situations—at home, in the classroom, on a field trip, in the library, or in the laboratory; and from these experiences, pupils are called upon to organize and apply the concepts and skills initiated and developed in their textbooks. Self-testing reviews are included for additional pupil evaluation and a Teacher's Correction Key, separately available, provides suggested answers.

TESTS

Teaching Tests, prepared and screened by the Harcourt, Brace & World Science Testing Board, are available separately for *Concepts in Science* 3 through 6. The answer keys are found in the Teacher's Editions of the textbooks.

These tests, to be used after each unit in the pupil's books, go beyond the testing of facts. Like other elements in the *Concepts in Science* program, they help teachers evaluate the pupil's understanding of concepts. The questions for each test are designed to evaluate comprehension as well as retention of information. They are divided into several parts; the parts are designed to test the child's ability to read for comprehension and interpretation, the ability to recall factual information, the ability to evaluate and apply concepts in new situations. They may also determine how well the pupils perceive relationships among the concepts developed.

LABORATORY CARDS

100 Invitations to Investigate, a set of 100 ungraded laboratory cards, provide the background information, illustrations, and clues to procedure for pupils' independent investigations. The investigations are a random assortment in the biological, physical, and chemical sciences; they progress in difficulty—the higher numbered investigations being more sophisticated. The cards, which are packaged in a sturdy case, are designed for those pupils who wish to pursue, beyond what is covered in the textbook, their own interest in some particular area of science, independent of their regular classroom work. Each child is encouraged to select the investigation in which he is interested, to investigate with enthusiasm and imagination, to seek answers to problems for which his textbook offers no solution. While designed for enrichment, the laboratory cards also lend themselves to science study by specially interested students and for science in ungraded programs.

SOURCEBOOKS FOR THE TEACHER

Harcourt, Brace & World publishes a number of professional books which provide supplementary information for teachers on how to plan, prepare for, and carry out a science program in the elementary school. Written by specialists in the field of science education, these books provide the "tactics and strategy" as well as the techniques for teaching elementary and high school science. They also employ the scientific and educational psychology involved in the teaching of science. You will find a list of these publications on the first page.

Part Two: CONCEPTS IN SCIENCE 6

Structure and Content

Concepts in Science 6 is more than a series of related sections. It is more than the sum of its separate parts. It is the last of a series of six books of an elementary science curriculum. It is the culmination of a sequential and fully articulated program in which each unit has dependence upon the contents of units previously studied. Each section in the textbook is part of the larger pattern of the unit. The unit, in turn, is part of a still larger pattern, the year's work in science, which encompasses the six conceptual schemes at the concept level indicated on pages F-14—F-15.

Science concepts are interrelated. Interdependence, for example, is the theme of the first three units, but heredity (the theme of Unit Eight) also plays a role, as do matter and energy, the themes of Units Four through Seven; and change is the theme of the last two units. These relationships become increasingly clear as the pupils study how technologists have made use of the concepts developed by scientists to invent machines, new products, new fibers, new means to insure longer life, better plants and animals, and complicated techniques and structures which have enabled us to take close-up photographs of the planet Mars. Concepts of science are introduced, reintroduced, and reused in every unit; out of the diversity of the world, the pupils see unity in the concepts that are used to do the world's work.

The conceptual schemes that are set forth in this Teacher's Edition, and the subconcepts which serve them, lend themselves to providing basic experiences for the pupils as they study the objects and events in the world around them. A concept learned in one unit is recalled and reapplied in new contexts in later units.

In *Concepts in Science 6* the nine units develop the sixth concept level of the six major conceptual schemes. Each unit is primarily concerned with one conceptual scheme, but some schemes appear in more than one unit. The nine units deal with a variety of subjects: behavior and learning, reflexes

and habits, new metals and fibers, bacteria and antibiotics, vaccines and viruses, machines and force, heat and motion, rockets and jets, electrons and electromagnetic waves, fission and fusion, chromosomes and DNA, stars and the changing universe—to give but a partial list. Yet, to the scientists, these units are concerned with only three larger categories: energy, matter, and life. These three categories have been studied in earlier textbooks in the series in an ascending order of sophistication in relation to what the authors have chosen to call the six major conceptual schemes—schemes that are basic to a pupil's understanding of the material universe. Life, matter, and energy will be studied again in succeeding years at still higher levels of sophistication.

Earlier concept levels for each conceptual scheme are basic to understanding the scheme as it is developed on this concept level. *Concepts in Science 6* builds upon earlier levels. The conceptual schemes are not *taught* to the children; rather, they are the goals the children, as learners, reach through experiences that have been selected to provide a maximum of individual involvement in the learning process. Concept formation has been proceeding step by step through all the grades, and will continue for every pupil.

The exploration of the environment, certainly a major aim of science, does not begin in the first grade, nor end in the sixth. Most young children enter school with a fund of science information (and misinformation) and a fairly well-developed pattern of behavior that has served their need to satisfy their natural curiosity. By the sixth grade they have had new experiences, many that have been planned in search of meaning. In school, their experiences have been selected and organized for conceptual understanding, a necessity if the search is to be successful.

In each grade, teachers help children to organize and evaluate their information, and to use and improve their habits and skills of investigating. Their

investigating, however, proceeds no longer in the random fashion of early childhood; rather, it proceeds through thoughtful selection of the processes of scientific investigation in a sequential, developmental pattern of experiences systematically organized as a science curriculum. Let us examine the pattern in *Concepts in Science 6*, as it is developed in the textbook and Teacher's Edition.

THE STRUCTURE OF A UNIT

All the units in the child's textbook have the same structure and the same component parts. All the units in this Teacher's Edition exactly parallel the structure of the child's textbook, except, of course, that the statements of the conceptual goals of the teaching and learning processes are not included in the child's textbook. All the teaching suggestions for each unit directly precede the reproduced pages of the child's textbook and are readily identifiable by the color bands on the outside margin.

Since you will be starting with Unit One, "Learned and Unlearned Behavior," a brief analysis of the teaching suggestions on pages T-1—T-19 will serve to explain the main headings and help in developing an approach to teaching the sections in this and subsequent units.

Across the top of page T-1 is a statement of the **Conceptual Scheme** followed by the **title of the unit** and a notation of the pages of the child's textbook to which the teaching suggestions refer. In the margin appears a statement of the **Unit Concept**. Reference to the chart on pages F-14—15 shows that this Unit Concept for Unit One thus deals with Concept Level VI of Conceptual Scheme C. Similarly, other units are seen directly to fit the same concept level of one or another of the six conceptual schemes.

Next to the Unit Concept statement is an interpretation for the teacher that is related to questions children are likely to ask, observations they may make, or procedures they will use in working toward the goal of concept formation and conceptual understanding.

In "A View of the Unit," which immediately follows the title of the unit, it is recognized that teachers have many claims upon their time and energies. This preview of the concepts not only summarizes the subconcepts that supply the evidential base for the unit concept but also provides

background information that often goes considerably beyond the sixth-grade level. It is hoped that this introduction will render it unnecessary that a teacher do further research before beginning to teach the unit with confidence and enthusiasm.

Under "Supplementary Aids" (see pages T-3—6), there is a graded listing of films and filmstrips for classroom showing, as well as books for the science reading table. The films and filmstrips have been previewed, selected, and rated by Bess S. King, formerly supervisor of Santa Monica Public Schools, Santa Monica, California. An "intermediate" rating indicates that the concepts are relatively easy to comprehend, while a "junior high school" rating indicates they are relatively advanced for sixth grade, but useful if their presentation is carefully guided. The books suggested for the science reading table were reviewed, selected, and graded for reading level and conceptual content by Ester K. Nelson, Consultant in Elementary Education, Bureau of Elementary Education, California State Department of Education, Sacramento, California. The authors of *Concepts in Science* unhesitatingly concur with the choices. The *Classroom Laboratory* and other items for a comprehensive program are described on pages F-17—18.

Suggestions for **Introducing the Unit** (see page T-6), together with the opening two pages of the unit in the child's textbook, serve to stimulate curiosity and link thought to action. They lead directly into the teaching suggestions for Section 1 of the unit.

The Pattern of a Section. Examination of the opening lines of a section (see Section 1, page T-6) reveals a pattern identical to that of the opening of the unit: the *title of the section*, the *pages of the child's textbook*, a *statement of the subconcept*, and an *interpretation for the teacher* that is related to the manner in which children will work toward understanding of the subconcept. Note that each subconcept is related to, and fills in, some aspect of the unit concept. Section subconcepts might well be considered as supporting concepts to the larger and more inclusive Unit Concept.

In the margin below the subconcept generally appears a listing of the **Processes emphasized** for the entire section. Not all processes will be used in every activity, nor will these necessarily be the only processes children will use. The teacher immediately sees, for example, that in Section 1 chil-

dren may be encouraged to observe, take a field trip, investigate, hypothesize, consult with others, report their findings, and invent models. By these processes, and others in different sections, children approach conceptual understanding.

In each section, the child has experiences that enable him to take a specific step toward understanding some important concept. A section may be completed in one day in some instances; in others, several days will be needed. A lesson in this textbook does not imply completion of so many minutes of a classroom assignment, but gaining of an understanding of a concept, even though the child has never seen or heard the concept stated in specific terms.

Like good lessons in subjects other than science, the section has three main divisions:

- the introduction*—in which a problem is raised and curiosity stimulated; that is, thought is linked to action;
- the main body of the lesson*—in which the content is organized for concept development and then summarized;
- the reinforcement or extension of the lesson*—in which a variety of activities is introduced for enrichment.

In the sections, or lessons, the children become aware of new relationships as they discover similarities among objects and events that previously may not have appeared to them to be related. Gradually, as they recognize and understand more clearly some of the more complicated patterns of relationships in the universe, for which they are ready on the fifth-grade level, the children build in depth their concepts in science. These concepts evolve in the child's mind as he takes each experience as a specific step toward understanding of increasingly mature concepts.

Introducing the Concept, the first part of each section, suggests an activity that raises questions or poses a problem. The activity may be a demonstration by the teacher, the making of a model, a class discussion, or a simple investigation. Occasionally some object or objects are desirable for examination. In Section 1 of Unit One (page T-6), this procedure is suggested, and the objects are listed as **Equipment and Materials** in the margin so that the teacher may see at a glance what may be

useful to obtain for the opening of the lesson. In fact, wherever any activities are suggested that call for materials, the teacher will find a listing in the margin with a space in which to check their availability.

Once the section has been introduced, the teacher may further stimulate and guide the children's attention and curiosity by asking the pertinent question in bold-face type. To work toward uncovering the answers, the children turn naturally to their science textbooks and continue with the main part of the lesson.

Developing the Concept consists of several activities, usually from three to five, indicated by italic headings. These activities help the child to uncover evidence, see relationships, draw inferences, and in other ways move further toward understanding of the concept. The kind of evidence the children should discover is stated in the margin opposite the italic title. Equipment and materials are listed if necessary, except for the investigations in the child's textbook where the materials are listed in the investigation.

The heart of many of the lessons, or sections, is the *investigation*, always indicated in the child's textbook by the blue-tinted pages. If pitfalls in the investigation can be anticipated, or other learnings or questions may evolve from it, the teacher is alerted in the teaching suggestions. Otherwise, teachers follow the child's textbook and encourage design of the investigation and performance of it at the point indicated. If special equipment or alternate equipment for the investigation is supplied in the *Classroom Laboratory*, the availability of this equipment is indicated in the margin (see pages T-12 and T-13).

It is useful at this point to call attention to the illustrations, both in the text and in the investigation pages. The concepts of science rest upon observed evidence; that is, evidence observed and verified by someone. Unfortunately none of us can observe everything at first hand; in fact, we must rely upon indirect evidence for much that we learn. The evidence of pictures is perhaps the hardest to read. We tend to look at a picture before we know what it is that the picture can tell us—and then we don't come back to it. Or we read all about an object or event before we look at the illustration and often overlook something important that would help fix our understanding. To insure that the picture is

"read" at the appropriate time, the picture is cued within the text by a symbol (square, circle, triangle, etc.) in color. Each cue means simply, "Now look at the picture—the one marked with a square." This is the right moment for inspection. There is no difficulty returning to the right point in the text, because the cue is there, clearly visible. Figure numbers and captions, used at higher levels of instruction, would tend, with younger children, to interrupt the reading or set the illustration apart from the context. This cuing of visualizations of evidence gives an improved degree of control over the learning situation.

In the child's text, the outcome of an investigation can be seen in the photographs illustrating it, as a rule. The text of the investigation does not tell what the outcome will be; the picture must be inspected to see what happened. Thus, the importance of seeing, or observing, is stressed, even if, for some good reason, the investigation is not actually performed. When it is performed, the child has a guide by which to test his own results. However, we must also stress that the photographs show only how *one* trial came out. Scientists seldom accept the evidence of one trial. Variations in the children's results are to be expected. There may be good reasons for the variations, or perhaps the technique may be faulty. Children, then, should be cautioned not to accept one result and encouraged to make several trials to discover reasons for any discrepancies between their results and those pictured.

Extending the Concept, part of the main body of the lesson, but not a requirement of it, provides additional activities in which children may seek out further information in an area that interests them or apply a developed understanding in a new context. Some of these activities are suitable for slower-moving children who need reinforcement on a lower level; others offer a challenge to the more able.

Each section in the child's text closes with several types of activities, ranging from simple self-tests to investigations children may do on their own. Since teachers are busy persons, the answers to factual questions are given under **Reviewing the Concept** (see page T-9). The results of a pupil-planned activity are not indicated. He may achieve a different answer that satisfies the conditions of his activity, or a more extended answer than might

be given here. What the child uncovers and can defend on the basis of his own efforts is far more important than his arrival at an expected answer.

A good science lesson rarely ends at the close of a science period. One of the criteria used by teachers in evaluating the effectiveness of their teaching is the enthusiasm with which children continue to observe and investigate on their own. The lesson (section) then serves to point the way and to give meaning to children's continuing observations and investigations in their daily lives.

Closing the Unit. The last section of each unit (see page T-17), titled "The Main Concept," brings the central ideas of the subconcepts together in a summary that relates them to the Unit Concept and to the Conceptual Scheme. It is at this time that children should be encouraged to formulate their own statement of the Unit Concept. The exact words, as printed in the margin, are not important. Each child has his own understanding; any reasonable approximation of a statement of concept relationships should be accepted.

A New View. A comparison of the six conceptual schemes of *Concepts in Science* (pages F-14—15) shows that all these schemes are interrelated. In the sixth grade, children can begin to see these concept relationships and get a glimpse of the unity of the world in which they live. Hence, at three stages during the year's course, children take stock of conceptual relationships in separate sections. The first of these is "A Concept of Interdependence: A New View," the second, "A Concept of Mass-Energy: A New View," and the third, "A Concept of Change: A New View." In each section, conceptual schemes are examined together as will be evident from a reference to pages T-69 and T-70 at the close of the teaching suggestions for Unit Three. The remaining two "New View" sections are at the close of Unit Seven and Unit Nine.

These "New View" sections encourage children to note and appreciate their growth in science. This growth is, of course, individual. But all the children come to some understanding of relationships between concepts. They can and do share an understanding of the world they have explored, each to his own capacity.

At the End of the Year's Work. Following the nine units and the final "New View" section is an end-of-book section titled "On Your Own: The Art of Investigation" (see textbook page 409). Many

children enjoy an extended activity; many are inveterate investigators; and still others are attracted by the opportunity to make discoveries on their own, quite independently of classroom experiences. The activities suggested in this section may be started with any child, with any group of children, or used to supplement the work of the text at any time. However this section may be used, it was prepared with the capacities of children to explore, investigate, and classify clearly in mind.

For all the children, the text, carefully ordered in concepts, growing in complexity as each child grows in maturity, provides a series of firm foundation stones on which all may be guided to a firmer understanding of the higher ordering of concepts in *Concepts in Science 6*.

The Ultimate Goal. Each science lesson is designed to permit the child to engage in the following processes.

1. to explore the material universe (through a "mix" of activity);
2. to seek orderly explanations of the objects and events explored (the explanation is an assertion we have called a *concept*);
3. to test his explanations (through a variety of activities).

The teacher's art is an individual one; the child's learning activity is an individual one. Nevertheless, the teacher's art is congruent to the scientist's when the child—in the teacher's hands—explores his world and, because of the teacher's great skill and understanding, is not crushed by the immensity of it.

Each lesson, in short, becomes an experience in search of meaning. A new concept of the way the world works becomes part of the child's equipment; it becomes part of his posture toward the world he lives in. He grows.

Useful Teacher References

Many books in science and science education offer splendid opportunities for additional study and investigations by pupils or for enrichment of teaching background. Harcourt, Brace & World publishes a number of textbooks for higher levels as well as several sourcebooks. Since they are referred to in this Teacher's Edition from time to time, the titles are cited below. In addition, a few other sourcebooks useful for reference and also cited in this Teacher's Edition are listed. Any of these is sufficient in conceptual depth and in richness of content to provide broad avenues of exploration for the most exacting teacher or the most inquisitive, imaginative, or creative child. The names and addresses of all the publishers whose titles are suggested here and in suggestions for individual units are on pages F-25—26.

The World of Living Things by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A general science textbook for junior high school, stressing biological science at an elementary level.

The World of Matter-Energy by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A general science textbook for junior high school, stressing earth and physical sciences at an elementary level.

Exploring the Sciences by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A complete, general science textbook for junior high school.

The Physical World, Second Edition, by Richard Brinckerhoff et al., Harcourt, Brace & World, 1963. A textbook in the physical sciences for ninth-grade pupils. Contains a special section of investigational activities for the more inquisitive and thoughtful pupil.

Teaching Elementary Science: A Sourcebook for Elementary Science by Elizabeth B. Hone et al., Harcourt, Brace & World, 1962. Descriptions of projects and experiments for pupils; techniques, field trips, demonstrations, and suggestions for planning instruction in biological and physical science are presented.

Teaching High School Science: A Sourcebook for the Biological Sciences by Evelyn Morholt et al., Harcourt, Brace & World, 1958. Similar in organization and planning to the elementary sourcebook cited above. Although designed for high school, it contains much useful material for the teacher and for pupils with special interests.

Teaching High School Science: A Sourcebook for the Physical Sciences by Alexander Joseph et al., Harcourt, Brace & World, 1961. Similar to the

biological sciences sourcebook cited above but for the physical sciences field.

Astronomy by Fred Hoyle, Doubleday, 1962. An encyclopedic volume of which the author states, "In this book I have attempted to take the reader from the earliest known astronomical discoveries up to the latest modern developments." Especially useful to teachers because of the indexing of both topics and illustrations.

Energy by Mitchell Wilson and the editors of *Life*, Time, Inc. From the *Life* Nature Library, Silver Burdett, 1963. In the introduction Glenn T. Seaborg queries, "But what, precisely, is energy?" This question the book answers, at least in part, by a wealth of information and brilliant photographs. Each of the eight sections is accompanied by a picture essay. Teachers and pupils will find the index useful for the study of selected topics.

Foundations of Modern Biology Series, Prentice-Hall, 1961. A series of short, illustrated books on modern biology. Hard-to-locate descriptions of recent research and discoveries may be found in these books. The titles of the books in the series are: *Man in Nature* by Marston Bates; *The Plant Kingdom* by Harold C. Bold; *Heredity* by David Bonner; *Animal Behavior* by Vincent Dethier and Eliot Stellar; *The Life of the Green Plant* by Arthur W. Galston; *Animal Diversity* by Earl D. Hanson; *Cellular Physiology and Biochemistry* by William D. McElroy; *Animal Physiology* by Knut Schmidt-Nielsen; *Animal Growth and Development* by Maurice Sussman; *The Cell* by Carl P. Swanson; and *Adaptation* by Bruce Wallace and A. M. Srb.

The History of Man by Gustav Schenk, Chilton, 1961. A concise but detailed story of the world of man as far as it is known at the present time.

Gives a comprehensive picture of the whole area of anthropology and genetics and an insight into the results of recent discoveries. Illustrations are on every page, many of them in color.

Machines by Robert O'Brien and the editors of *Life*, Time, Inc. From the *Life* Nature Library, Silver Burdett, 1964. That "machines provide the means through which matter's conversion into energy is made available for man's use" is the theme of the book. From an introductory section, "The Machine-made Fabric of the American Dream" and accompanying picture essay, "The Five Fundamental Machines," to the eighth section, "The Promise and Problems of Automation," the narrative and numerous illustrations, photographs, and diagrams, many of them in color, both inform and delight the reader.

Teaching Science Through Discovery by Arthur Carin and Robert B. Sund, Merrill, 1964. An intensely practical volume which can help teachers understand and practice a science program for the elementary school in accordance with the revolutionary nature of science education. The four section titles, "Shaping Science Education in the Elementary School," "Organizing and Planning for Teaching Science," "Enrichment Activities for Science Teaching-Learning," and "Discovery Lesson Plans and Other Activities for Teaching Science," barely suggest the rationale and framework for science instruction and learning which permeate all sections. Emphasis is on problem-solving and the "discovery approach," but specific, detailed, and step-by-step teacher activities for organizing, planning, and teaching science are given. The appendix contains bibliographies of professional books, sources of scientific equipment and supplies, and many other helpful lists.

ADDRESSES OF PUBLISHERS

Basic Books	Basic Books, Inc., 404 Park Ave., S., New York, N.Y. 10010
Benefic Press	Benefic Press, 1900 N. Narragansett, Chicago, Ill. 60639
Bobbs-Merrill	The Bobbs-Merrill Co., Inc., 4300 W. 62nd St., Indianapolis, Ind. 46206
Chilton	Chilton Co., Book Division, 525 Locust St., Philadelphia, Pa. 19106
Creative Educational Society	Creative Educational Society, Inc., Mankato, Minn. 56001
Crowell	Thomas Y. Crowell Co., 201 Park Ave. So., New York, N.Y. 10003
Dodd, Mead	Dodd, Mead & Co., Inc., 432 Park Ave. So., New York, N.Y. 10016
Doubleday	Doubleday & Co., Inc., 277 Park Ave., New York, N.Y. 10017
Dutton	E. P. Dutton & Co., 201 Park Ave. So., New York, N.Y. 10003
Harcourt, Brace & World	Harcourt, Brace & World, Inc., 757 Third Ave., New York, N.Y. 10017
Harper & Row	Harper & Row, Publishers, 49 E. 33rd St., New York, N.Y. 10016
Harvey House	Harvey House, Inc., Irvington-on-Hudson, N.Y. 10533
Houghton Mifflin	Houghton Mifflin Co., 2 Park St., Boston, Mass. 02107
John Day	The John Day Co., Inc., 200 Madison Ave., New York, N.Y. 10016
Knopf	Alfred A. Knopf, Inc., 501 Madison Ave., New York, N.Y. 10022
McGraw-Hill	McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York, N.Y. 10036
Macmillan	The Macmillan Co., 60 Fifth Ave., New York, N.Y. 10011
Melmont	Melmont Publishers, Inc., Jackson Blvd. & Racine Ave., Chicago, Ill. 60607
Merrill	Charles E. Merrill Books, Inc., 1300 Alum Creek Dr., Columbus, Ohio 43216
Messner	Julian Messner, Inc., 8 W. 40th St., New York, N.Y. 10018
Morrow	William Morrow & Co., Inc., 425 Park Ave. So., New York, N.Y. 10016
Pantheon Books	See Random House
Parents Magazine Press	Parents Magazine Press, 52 Vanderbilt Ave., New York, N.Y. 10017
Prentice-Hall	Prentice-Hall, Inc., Englewood Cliffs, N.J. 07631
Putnam's	G. P. Putnam's Sons, 200 Madison Ave., New York, N.Y. 10016
Rand McNally	Rand McNally & Co., Box 7600, Chicago, Ill. 60680
Random House	Random House, Inc., 457 Madison Ave., New York, N.Y. 10022
Scholastic Book Services	Scholastic Book Services, 904 Sylvan Ave., Englewood Cliffs, N.J. 07631
Scribner's	Charles Scribner's Sons, 595 Fifth Ave., New York, N.Y. 10017
Singer	L. W. Singer Company, 249 W. Erie Blvd., Syracuse, N.Y. 13202
Simon and Schuster	Simon and Schuster, Inc., 650 Fifth Ave., New York, N.Y. 10020
St. Martin's Press	St. Martin's Press, Inc., 175 Fifth Ave., New York, N.Y. 10010
Time, Inc.	Time, Inc., Book Division, Time-Life Bldg., Rockefeller Center, New York, N.Y. 10020
World Publishing	World Publishing Co., 2231 W. 110th St., Cleveland, Ohio 44102

ADDRESSES OF AUDIOVISUAL SUPPLIERS

The teaching suggestions for each unit of this Teacher's Edition list a number of films and filmstrips for classroom showing. Orders or further

requests for information should be addressed to the following distributors or suppliers whose names are given in abbreviated form at the left.

Cenco	Cenco Educational Films, 1700 Irving Park Rd., Chicago, Ill. 60613
E.B.F.	Encyclopaedia Britannica Films, Inc., 1150 Wilmette Ave., Wilmette, Ill. 60091
E.F.D.	Educational Films Division, John Colburn Associates, 1122 Central Ave., Wilmette, Ill. 60091
F.A.	Film Associates of California, 10521 Santa Monica Blvd., Los Angeles, California 90025
Jam Handy	Jam Handy Organization, 2821 E. Grand Ave., Detroit, Michigan 48211
McGraw-Hill	McGraw-Hill Publishing Co., Text Film Dept., 330 W. 42nd St., New York, N.Y. 10036
S.V.E.	Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill. 60614

Answer Key for TEACHING TESTS

Unit One

1. a
2. d
3. c
4. a
5. b
6. b
7. b
8. c
9. a
10. d
11. reflex act
12. instinct
13. learned act
14. habit
15. theory of conditioning
16. b
17. c
18. c
19. a
20. d

Unit Two

1. a
2. a
3. b
4. b
5. a
6. b
7. a
8. a
9. d
10. b
11. stainless steel
12. plastic
13. rayon
14. nylon
15. bronze
16. a
17. c
18. c
19. d
20. d

Unit Three

1. b
2. a
3. a
4. b
5. b
6. a
7. c
8. b
9. d
10. d
11. polio
12. smallpox
13. typhoid
14. tuberculosis
15. polio
16. b
17. d
18. b
19. c
20. a

Unit Four

1. b
2. a
3. b
4. a
5. b
6. c
7. d
8. c
9. c
10. a
11. wedge
12. wheel and axle
13. lever
14. inclined plane
15. screw
16. d
17. b
18. a
19. c
20. c

Unit Seven

1. hydrogen
2. magnesium
3. carbon
4. sodium
5. oxygen
6. d
7. a
8. b
9. b
10. c
11. atomic pile
12. generator
13. cloud chamber
14. Geiger counter
15. cyclotron
16. b
17. b
18. c
19. a
20. c

Unit Five

1. b
2. a
3. a
4. a
5. b
6. d
7. a
8. d
9. b
10. b
11. automobile engine
12. piston steam engine
13. steam turbine
14. rocket engine
15. jet engine
16. c
17. a
18. b
19. c
20. d

Unit Eight

1. c
2. b
3. a
4. c
5. a
6. c
7. d
8. a
9. b
10. b
11. fruit fly
12. seedless orange
13. mule
14. Rival wheat
15. Hereford cattle
16. c
17. a
18. a
19. d
20. c

Unit Six

1. a
2. a
3. b
4. b
5. b
6. d
7. a
8. a
9. d
10. b
11. bell
12. electric motor
13. telegraph
14. telephone
15. television
16. c
17. d
18. a
19. d
20. c

Unit Nine

1. a
2. b
3. a
4. b
5. b
6. c
7. b
8. a
9. c
10. b
11. Algol
12. Polaris
13. Alpha Centauri
14. Antares
15. Barnard's Star
16. a
17. d
18. d
19. c
20. d

6

Concepts in SCIENCE

PAUL F. BRANDWEIN

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ILLUSTRATORS

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CONTENTS

About This Book	1
UNIT ONE LEARNED AND UNLEARNED BEHAVIOR	3
1. Perfect—Without Learning, 4 • 2. From the Hydra to Simple Learning, 12 • 3. You Learn a “New” Behavior, 21 • 4. Making Learning Easy, 32 • 5. The Main Concept: Changing the Environment Through Learning, 38	
UNIT TWO IDEAS AND TOOLS: FOR NEW PRODUCTS	46
1. Charles Hall and His Discovery, 48 • 2. Uses of a Concept, 57 • 3. The Uses of Ideas and Tools: New Metals, 68 • 4. The Uses of Ideas and Tools: New Fibers, 84 • 5. The Main Concept: Changing the Environment Through Science and Technology, 91	
UNIT THREE IDEAS AND TOOLS: FOR LONGER LIFE	98
1. Organisms We Cannot See, 100 • 2. Unwelcome Organisms, 104 • 3. Your Body’s Defenses, 110 • 4. Molds to the Rescue, 117 • 5. Another Battle: Another Victory, 124 • 6. Health—A Public Concern, 131 • 7. The Main Concept: Controlling the Environment, 139	
A CONCEPT OF INTERDEPENDENCE: A NEW VIEW	146
UNIT FOUR MACHINES IN ACTION	152
1. Multiplying the Force of Your Muscles, 154 • 2. The Levers You Use, 161 • 3. Uses of Pulleys, 165 • 4. Other Machines You Use, 172 • 5. A Resisting Force, 180 • 6. Is More Work Done? 183 • 7. The Main Concept: Energy, Machines, and Work, 189	
UNIT FIVE MOLECULES IN ACTION	194
1. A Modern Genie, 196 • 2. An Explosive Genie, 205 • 3. Balloons and Planes—Going Up, 212 • 4. Jets and Rockets, 218 • 5. The Main Concept: The Use of Moving Molecules, 224	
UNIT SIX ELECTRONS IN ACTION	230
1. “Rubbing” Off Parts of Atoms, 232 • 2. Generating an Electric Current, 238 • 3. Electric Bells and Electric Motors, 247 • 4. Electric Signals, 257 • 5. Relays Without Wires, 268 • 6. The Main Concept: Changing and Transferring Energy, 279	

UNIT SEVEN MATTER INTO ENERGY

1. Inside an Atom, 286 • 2. Splitting the Nucleus, 294 • 3. Nuclear Reactions, 302 • 4. Uses of Nuclear Energy, 308 • 5. The Main Concept: Particles of Matter, 314

A CONCEPT OF MASS-ENERGY: A NEW VIEW

284

321

UNIT EIGHT CODE OF HEREDITY

1. A "Chip off the Old Block," 326 • 2. Inheriting Traits, 332 • 3. Crossing Plants, 336 • 4. Blending Traits, 342 • 5. Changing the Code, 346 • 6. The Search for Prize Genes, 355 • 7. The Main Concept: The Genetic Code, 359

324

UNIT NINE STARS AND STARLIGHT

1. Energy from a Star, 366 • 2. The Temperature of a Star, 372 • 3. Numbers of Stars, 380 • 4. The History of a Star, 387 • 5. Motions of the Stars, 392 • 6. The Main Concept: The Changing Universe, 397

364

403

ON YOUR OWN: THE ART OF INVESTIGATION

KEY CONCEPT WORDS: A BEGINNING VOCABULARY FOR SCIENCE

INDEX

409

422

430

CONCEPTUAL SCHEME

Living things are interdependent with one another and with their environment.

Unit One

LEARNED AND UNLEARNED BEHAVIOR

(Text pages 2-45)

As each child grows and develops, he increases in understanding and in the capacity to learn; he begins to appreciate that some of his responses to stimuli are inherited (inborn and automatic) and that some responses can be changed as he uses the structures he has inherited. In this unit, the pupils examine two theories, conditioning and goal-insight, that help explain how they learn. They investigate how they can change their behavior and gain greater control over their environment.

UNIT CONCEPT

Living things are adapted by structure and function to their environment.

A VIEW OF THE UNIT

By this time in their school course, your pupils have had considerable work in science. They have examined their experiences, raised questions, formulated hypotheses, built models, and performed investigations to gather information that either verified or challenged their hypotheses. They have interpreted and organized data, made generalizations, consulted living persons and written sources as authorities, and—most useful of all—they have formulated concepts that help them organize and explain the events and objects in the world around them.

A Preview of the Concepts

In this first unit of *Concepts in Science 6*, the pupils examine how they have used their brains and inherited characteristics and thus have been able to learn and will continue to learn as long as they live. They examine some of the concepts that underlie our understanding of how they—and other organisms—respond to stimuli in their environment. Several theories that have borne the test of investigations and experiments by psychologists are presented to help explain these responses and the ability of man, alone among all organisms, to learn and to apply what he has learned to the solution of his problems.

As the pupils study later units, they will see how this ability to learn has led many students to formulate useful concepts to explain observed phenomena and to modify these concepts as new data are discovered. The formulation and testing of concepts is the chief work of the *scientist*. These concepts may then be stimuli to others who attempt to find useful applications—that is, to invent tools—for changing or controlling the environment. The discovery of applications is the chief work of the *tech-*

Science and Technology

nologist. But both the scientist and the technologist work together; both are learners and discoverers.

During the year, each pupil will formulate and modify concepts—as he has been doing in earlier years. He will, in his investigations, invent tools for obtaining more accurate and precise data. He will, within the extent of his capacities, be both scientist and technologist. This unit lays the groundwork for his understanding of the uses and tools of the scientist, the greatest of which is the human brain with its capacity to observe, think, generalize, and invent. As living things, the pupils are products of their heredity and environment. They have, of course, been learning in earlier years; *now*, they learn about learning. And they investigate how they can apply this knowledge consciously.

The pupils study inborn and unlearned acts (reflexes and instinctive behavior) of common animals and of themselves. For every stimulus there is a response. Scientists have become cautious about using the term instinct as a type of behavior apart from learned or inborn behaviors. Except for true tropisms in plants (turning of leaves to light or roots to water), very few behaviors can be said to be completely inborn. Most types of behavior are modifiable. As pupils will discover, many reflexes may be conditioned—that is, modified—by building a new stimulus into the stimulus-response pathways of the nervous system. A few reflexes, such as heartbeat and the response of the pupil of the eye to light, cannot be modified.

Understanding of conditioning (through the reward stimulus) paves the way to understanding habit formation and other more complex learning processes. What internal communication system do organisms have that keeps them in touch with and responsive to the environment? The pupils consider the nervous system of the hydra and their own. In order to develop the relationship of the nervous system to the other systems of the body, it may be helpful to borrow wall charts of the human body from the high school biology department if you do not have charts of your own. Or circulate a copy of *Concepts in Science 5*, which has an entire unit, Unit Five, on the human body, including a number of useful diagrams.

Psychologists have many devices in their laboratories for study of animal behavior. One such device is a cage with a colored square on which an animal must step in order to release food in a holder. In this way scientists study relative rates of learning in experimental animals. You can duplicate this device in a simple way by using, as a food holder, a box that can be opened and shut quickly so that you can manually give the reward. If you have some skill and training and are fortunate enough to have access to animals for demonstration, you may wish to make advance plans for illustrating the role of reward in learning. A simpler device that is easy to construct is a maze, a T-maze for an earthworm and more complicated mazes for mammals. You can demonstrate the role of reward in learning, or careful and interested volunteers can

investigate it. See page 132 of *The Sourcebook of the Biological Sciences* for directions.

From conditioning and simple learning, the text proceeds to habit formation and the goal-insight theory of learning. It is well to think of the process of learning as not separate, but related; sometimes we seem to act automatically, and, at other times, only after careful thought, depending on the stimuli. The mammalian brain has a highly developed mass of millions of interconnected neurons, in turn connected throughout the body—as compared with the simple nerve net of the hydra. Man's brain has about 5 billion of these neurons which free him from relying on automatic response to stimuli, and permit him to develop responses that are rooted in experience and learning. That is, he can develop habits or change them; he can look ahead to a goal and see ways of reaching it; and he can test his responses.

The pupils review the concept that organisms are adapted to their environment. We might also say that man is adapted for learning. Hence out of their study, your pupils may become encouraged to examine their goals and make plans to achieve them. Science may help them become efficient learners, the long-term goal of spending 12 to 16 years or more preparing to operate responsibly in the environment of their tomorrow.

SUPPLEMENTARY AIDS

All the films and filmstrips below are in color unless otherwise indicated. In order to have them available at the time you wish to show them, it is advisable to order or reserve them on loan from the supplier well in advance. The names and addresses of distributors of films and filmstrips, listed here by abbreviation, are given on page F-26. Following each film or filmstrip is a rating of the approximate range of content and difficulty. Those that are rated "Intermediate" are, in general, about right for the grade level. All the available films and filmstrips dealing with behavior tend to be advanced in difficulty and are rated "Junior High." Previewing and advance lesson planning is suggested.

Animal Habitats (11 min.), F.A. Illustrates the relationship between living things and the habitats in which they are found. Simple introduction to principles of ecology. (Intermediate)

Balance of Life and the Space Age (13½ min.), F.A. Considers the earth's living things in terms of their basic needs; interdependence of plants and animals. It will be necessary for man to create a balanced system inside a space capsule to keep astronauts alive. (Intermediate)

Response in a Simple Animal (11 min.), F.A. Unique microphotography illustrates how a simple animal responds to different changes or stimuli. (Intermediate)

Environment and Survival (10 min.), F.A. A study of the problems of survival faced by a trout in a rocky stream. Highly developed instinctive patterns determine its habits. (Intermediate)

Habit Formation and the Goal-insight Theory

Adaptation

Films

Habit Patterns (15 min., black-and-white), McGraw-Hill. Shows the social and personal advantages resulting from early formation of orderly and systematic habits in contrast with lack of advantages in a person who has not developed such habits. (Junior High)

Behavior in Animals (14 min., black-and-white), McGraw-Hill. Shows that animal behavior is the organism's overall reaction to its external and internal environments. Levels of behavior shown; simple reflexes and conditioned responses. (Junior High)

Behavior of Living Things (40 frames, black-and-white), McGraw-Hill. Presents biology in terms of broad generalizations accompanied by meaningful illustrations and examples. Shows that animals lower than man seem capable of working with ideas to a limited degree. (Junior High)

What Is Behavior? (48 frames), McGraw-Hill. The way that living things respond to change is called behavior; examples are given of inborn behavior of simple reflex and conditioned reflex. Man acquires new habits through learning. (Junior High)

Having books on a reading table in one part of the room for free reading investigation from time to time is a stimulus to interest in elementary science. Many titles are available and more are continually being published. The ones below have been found useful for this unit; those starred (*) are especially recommended as having suitable sections for enlarging upon the content and concepts of this unit. Following each title appears a rating of the reading level in relation to that of the pupil's textbook. The full names and addresses of the publishers are on page F-24.

**All About Biology* by Bernard Glemser, Random House, 1964. The three parts, "The Beginnings of Life," "Some Great Discoveries in Biology and Animals of One Cell," and "Animals of Many Cells," barely suggest the extensive coverage of this remarkable book. Excellent photographs. (Average)

**All About the Human Mind* by Robert M. Goldenson, Random House, 1963. Describes how personality develops, how the brain works, why people behave as they do, and how mind and body work together. The animal and human mind are compared and feelings and emotions are discussed in relationship to the mind. (Average)

Animal Clocks and Compasses: From Animal Migration to Space Travel by Margaret O. Hyde, McGraw-Hill, 1960. Many pieces of the puzzle of animal clocks and compasses are described. Includes information on the language of bees, the journey of whales, the migration of turtles, and the amazing sense of time and direction displayed by many other animals. (Average)

Coral Reefs by Lois and Louis Darling, World Publishing, 1963. The main types of reefs—fringing and barrier reefs and atolls—are described. Included also is information about plankton, the coral polyps, sea anemones, echinoderms, mollusks, crustaceans, and vertebrates and their interdependence with the reefs. (Advanced)

The Courtship of Animals by Millicent E. Selsam, Morrow, 1964. Courtship among fish, amphibians, reptiles, birds, mammals, insects, and spiders is described. Includes recent research and many illustrations. (Average)

How Smart Are Animals? by Helen Kay, Basic Books, 1962. By studying the behavior of animals and the ways in which they learn, psychologists have found out a great deal about human learning. This book tells of experiments to learn more about the intelligence and learning abilities of dogs, cats, rats, birds, elephants, dolphins, chimpanzees, and other animals. (Average)

The Language of Animals by Millicent E. Selsam, Morrow, 1962. Findings of experimentation in animal communication are described. Studies of mammals, frogs, snakes, alligators, birds, and insects are included. (Average)

The Strange World of Animal Senses by Margaret Cosgrove, Dodd, Mead, 1961. Explains some of the development of senses up through the various groups of animals. The senses of touch, taste and smell, vision, hearing, sets of senses, and the sixth sense are considered. (Advanced)

**The Tale of a Pond* by Henry B. Kane, Knopf, 1960. A full year's cycle of the interrelationships of plants and animals in a pond, on its surface and in its depths, is told by a careful and patient observer. Excellent photographs supplement the narration. (Advanced)

Wonder-Workers of the Insect World by Hiram J. Herbert, Dutton, 1960. Activities of the insect world described in this story include closeups of life cycles and accounts of the skill, ingenuity, and adaptability of fourteen individual species. Contains a wealth of information and exciting reading. (Advanced)

In addition to planning in advance for films, filmstrips, and books for yourself and the science reading table, it is well to check beforehand on materials you have available for demonstrations and investigations. Throughout this Teacher's Edition, marginal notations are given under the heading "Equipment and Materials" wherever an investigation is suggested to supplement the work of the pupil's textbook. These materials are usually readily available in the classroom or easily obtainable by pupils from local or home resources.

The pupil's textbook, *Concepts in Science 6*, includes a number of investigations, indicated by a blue tint on the pages on which they occur. The equipment needed is listed at the beginning of the investigation. The number of items you will need to have on hand depends on whether you plan to use the investigation as a demonstration or to have pupils work individually or in groups. For efficient investigating, materials should be gathered in advance or ordered, if necessary, from the school supply room.

As more fully described on pages F-17-18, a set of laboratory equipment and materials, *Classroom Laboratory 6*, to accompany *Concepts in Science 6* is available from the publisher. The materials are conveniently packaged so that six groups of pupils may work on an investigation at one time. An exception is that a few standard items, such as alcohol lamps,

*The Classroom Laboratory—
Assembling and Organizing
Materials*

are provided singly. Most of the investigations in *Concepts in Science 6* can be performed by using these materials, which are the same or similar to those suggested on the investigation pages. Notations are given in the margin of this Teacher's Edition for each investigation for which materials are provided. If you have *Classroom Laboratory 6*, it is useful to refer to Part II of the Teacher's Manual included in it. You will find suggestions for carrying out the textbook investigations and other investigations that extend the concepts.

► INTRODUCING THE UNIT

This unit is about learning. How do you learn? Certainly, when you were born, you could not say a word. Until you started school, you couldn't write very much—perhaps only your name. You, and all other human beings, are able to use language. Were you born with this ability? Language is a way of passing on what you have learned so that someone else can get along better—or help you learn more. Think of all the things you do during the day, and list them in two columns to indicate abilities you were born with and others that you acquired as you grew older. The list should tell you that most of the things you do had to be learned. But *how* did you learn to do them? As the pupils hazard guesses—some random and some educated—record them without comment. You may wish to synthesize some of the responses with the pupils and reduce the list. In any event, you will have started them thinking. Pose the question: Can any of these things be done perfectly, without thinking? How about others in the list? Did someone use language to pass on his experiences to you? What did you have to do? In a word, how do you think you have been able to learn all you know in 11 or 12 years?

The chances are you will have many random answers to the above questions. You will now be ready to proceed with an organized development of the sections in the unit and to encourage the pupils to refine their thinking and formulate some eventual goals for their work this year in science—and in other school subjects as well.

Section 1: PERFECT—WITHOUT LEARNING

The pupil begins to understand some of his own reflex acts by examining the behavior mechanisms of simpler organisms as they respond to their environment.

Introducing the Concept

Do we have to learn everything we do? Are there some actions we can do without thinking? From the pupils' suggestions develop these chalkboard lists: INBORN (unlearned) ACTS and LEARNED ACTS. They may

(Text pages 4-11)

SUBCONCEPT

Behavior may be inborn and involuntary.

suggest some inborn responses that are actually automatic (learned) habits; but do not be concerned with that at this time. You may wish, also, to set up a third column of actions that pupils do not agree upon.

What kinds of actions do we do without thinking? Or do we have to think about everything we do?

Now refer the pupils to the beginning of the lesson and let them engage in the investigation on text page 5.

Developing the Concept

Reflexes and instinctive behavior. After the investigation, pupils may read the text through "Inborn Acts in Animals." They may need further help in clarifying the differences between reflexes and instincts, and between instincts and intelligent action. A *reflex* is a simple response to a stimulus. What happens if you touch the antennae or the soft, foot part of a moving snail? (It withdraws into its shell.) Pupils may suggest other animals sensitive to touch—or to light or sound. What are some complicated acts that animals, such as birds and insects, seem always to do in the same way? Compare the withdrawal of the snail—a relatively simple act—with nest building, a complicated series of acts, sometimes called *instinctive behavior*.

Are birds, spiders, or ants intelligent? Or is their behavior a series of complicated reflexes? Why? (Intelligent behavior requires thought before a response is made.) The point you may wish to make, through discussion, is that any behavior that can be modified is not completely inborn. Can you modify heartbeat or the digestion of food by thinking about it?

An organism's communication system. What makes you tick? What is inside your body that helps you respond to stimuli? (Brains and nerves.) Do simple animals have nerves? Encourage the pupils to read about the hydra (text pages 7–9). They learn that the hydra has no brain, but a nerve net that gives it the capacity to be "irritable" to its environment. To make the analogy with such an organism's nerve net, try to obtain a discarded printed circuit of a radio set. Pupils may be able to help you locate one in a TV or radio repair shop. Be sure that they clearly understand that nerve impulses and electric currents are not identical. For example, electricity travels through wires at a speed of several hundred miles per second; nerve impulses average about 400 yards per second or $3\frac{1}{2}$ miles per minute.

A jellyfish is related to the hydra. What kind of communication system would it be likely to have? (Nerve net.) Interested pupils may develop an umbrella model after viewing a picture of the shape of the jellyfish with tentacles hanging from the outer rim. A nerve ring may be molded with colored wire and the tentacles with lengths of yarn. The long central stalk could be made of heavier wire or several strands of light wire twisted together. (In review of earlier work, or to test the thinking of the pupils at the beginning of this year's work, you may wish to question them on the advantage of making models. They help children—as well

Responses to stimuli may be simple or complex.

Processes emphasized

Model building
Explaining
Observation
Theorizing
Investigating (and designing)
Analysis of experiences
Hypothesizing
Library research

Living organisms have structures that enable them to respond to stimuli in their environment.

Equipment and Materials

... wire (light and heavy weight)
... yarn

as scientists—explain something that is not easily seen or otherwise demonstrable.) As the jellyfish swims, it controls muscle cells by nerve threads extending from the main ring. What if the jellyfish had no nervous system? (Its parts would be unable to work together in response to stimuli from its environment.)

Extending the Concept

Can reflexes be changed by a different stimulus? What happens when you taste a lemon, a sour pickle, a choke cherry, or a persimmon? (The mouth puckers.) As you mention these—or other sour-tasting substances—some pupils' faces may pucker or they may shudder, even without seeing or tasting. Is their response to the words learned or inborn? (Learned.) Is the puckering response to tasting learned or inborn? (Inborn.) What change in the response has taken place? (Words have been substituted for tasting.)

Do plants always respond to stimuli in the same way? The term *tropism* rather than *reflex* is generally used for plants, but the concept of response to environment is valid. Pupils may sprout seeds inside a plastic Petri dish or between glass squares tied or taped over wet blotting paper. Every few days give the container a quarter turn. How do the roots react? Always toward the earth? (Yes.) Ever away from the earth? (No.) Pupils may try planting onion sets upside-down in a milk carton from which one side has been cut and replaced with a pane of glass. Since roots grow away from light, keep the glass side darkened with cloth or thick paper to promote root growth close to the glass.

Demonstrating irritability. If you have access to land snails, set one on a pane of glass, sprinkling the snail lightly with water. When it starts to come out of its shell and move about, place an apple core, or other food fragment, a short distance from it. As the snail moves toward the food, graze the edge of its foot muscle with the tip of a broom straw. (The snail will withdraw into its shell.) Repeat, timing the response intervals, with varying stimuli, e.g., light, texture, noise, and household substances, such as salt.

Are all skin surfaces equally "ticklish"? Pupils can be asked to contribute from their own experiences. Back of the neck? Palms of the hands? Soles of the feet? What happens if you brush the pads of a dog's hind paws when it is sleeping? (The paws jerk away.)

Complexity of inborn behavior patterns. Children can appreciate the complexity and perfection of certain types of animal behavior by trying to build a facsimile bird's nest from sticks, straw, and mud; or a spider's web from thread.

Demonstrating responses to light. If earthworms are available, a lively one may be placed on a damp paper towel. Darken the room and note its response to a flashlight. It will withdraw. Pill-bugs, unlike earthworms, will move towards light. Children may also report their own observations of the response of insects to light.

Equipment and Materials

- ... seeds
- ... plastic Petri dish or glass plates
- ... blotting paper
- ... milk carton
- ... onion sets

Equipment and Materials

- ... land snails
- ... food for snails
- ... broom straw

Equipment and Materials

- ... sticks
- ... straw
- ... thread
- ... earthworms
- ... paper toweling
- ... flashlight

An earthworm's nervous system. An interested child may wish to investigate and report on the nervous system of the earthworm, which is more complex than the nerve net of the hydra. He should consult a high school biology text. He may also be ingenious enough to build a model with beads and wire showing the nerve stations of each segment, and their connections through the length of the animal.

Reviewing the Concept

Suggested answers are provided, unless they are the result of a pupil's investigation. Obviously no fixed or, sometimes, even approximate answers can be given for "On Your Own" activities. Any approximation of an answer provided in this section should be accepted if the pupil's response indicates knowledge of concepts or information.

Before You Go On. A. 1. a 2. a 3. b 4. a 5. b 6. b 7. a 8. b 9. b 10. a B. The idea to be included is that a stimulus is a change in the environment; a response is an attempt to adapt to the change.

Using What You Know. 1. Tennis-playing is not an inborn act. Good playing takes practice. Peter may have inherited the body frame from his father, but not ability without learning. 2. A nerve net.

On Your Own. The stems will turn towards the light, an inborn response of plants. Any change in direction of growth will be due to changing their orientation to light.

Section 2: FROM THE HYDRA TO SIMPLE LEARNING

The pupils, by studying simple responses to simple stimuli, make the first steps toward appreciating how learning is an adaptation of an organism to its environment.

Introducing the Concept

Possibly the most useful introduction to an appreciation of stimulus-response behavior is to involve the pupils at once in the knee-jerk and other reflexes (directions for which are given in the investigation at the beginning of the section). After they have had sufficient opportunity to try out the reflexes involved, encourage them to raise questions. If the following questions are not proposed, initiate discussion.

What kinds of activities must living things perform to survive in their environment? What kinds of structures (organ systems) keep living things in touch with the environment and enable them to respond?

Then before, or concurrently with, the following suggestions, encourage reading of the section while thinking about the above questions.

Developing the Concept

With what structures do we communicate? How do persons work together? (They communicate; that is, each individual is responsive to

Equipment and Materials

... beads
... wire

(Text pages 10-11)

(Text pages 12-21)

SUBCONCEPT

Behavior consists of responses to changes (stimuli) in the environment.

Processes emphasized

Reading
Analysis of experiences
Discussion
Hypothesizing
Investigation (with design of experiment)
Making inferences
Categorizing
Predicting
Explaining
Model building (inventing)
Observation
Theorizing
Reporting

An organism's specialized structures enable it to interact with the environment.

Equipment and Materials

... parcel post twine or picture wire

A response may be changed by substituting a new stimulus and associating it with the original stimulus.

Equipment and Materials

... picture wire
... uncooked macaroni

other individuals through his sense organs.) What system do you have that enables you to sense your environment and do something about it? How do the cells in your finger work together if you touch a sharp object? Encourage "reading" of the diagrams of the nervous system and of the structures of nerves (text pages 12, 14, and 15). Pupils may be concerned about scientific terminology. Be sure they realize that a *neuron* is the scientific term for nerve cell, but that a *nerve* is a bundle of nerve fibers leading from one part of the body to another. Each bundle frays out at the end so that individual nerve endings are in contact with other kinds of cells—skin and muscle cells and other nerve cells, for example. Picture wire, or parcel-post twine, frayed out at the ends, is a useful model.

How can the kinds of nerve cells be recognized? It will be worthwhile to point out, if the class does not readily see it, that the nucleus of a sensory nerve is along the fiber *outside* the spinal column. The nucleus of the connecting nerve cell and of the motor nerve cell is *inside* the spinal column (or the brain). The illustrations on the text pages should clear up any confusion between the types of nerve cells. How do the three kinds of cells work together in a reflex? In what ways is a reflex useful to you? (Blinking and pulling away from a hot object protect you from injury; breathing and heartbeat maintain body functions; etc.)

Can a reflex be changed? Before the pupils read text pages 16 and 17, encourage sharing of experiences they may have had with pets. Most pupils have turtles or goldfish, dogs or cats, hamsters or reptiles. Have you trained your pet to do anything special or unusual? How did you do it? If the classroom has an aquarium, the investigation into the training of a fish can be planned and carried out cooperatively. It is important that a regular plan be agreed upon and followed rigorously for best results. Pupils may wish to design an investigation in changing the behavior of their own pet at home or training it to perform a new act. They should first submit their plan, and then report at a set time a few days or a week later. Encourage comparison and analysis of the training method in the light of stimulus-response. How was the S-R bond (text page 18) developed? What kind of nervous system does your pet have? (Brains and several types of nerves.) Which do you think would be easier to train—a hydra or an earthworm? Why? (Hydra has a simple nerve net, but an earthworm has a more developed nervous system.)

Extending the Concept

Modeling a nerve. How long must a sensory neuron be to tell you that something is tickling your toe? How long must the motor neuron be? (2 to 3 feet.) Pupils may model a motor nerve, or a sensory nerve, or the full reflex arc. Like electric wiring, the long threadlike fibers from the center of the nerve cells are wrapped in a protective sheath. To represent a motor nerve, pupils may thread many-stranded picture wire through lengths of raw macaroni, fraying out the ends of the wire. The ends may be attached to a poster drawn by a pupil with drawing or

artistic ability. The poster should show the muscle cells to which the wires lead. If the complete reflex arc is shown, encourage pupils to devise their own design for the connecting neurons and the sensory neurons. These may be modeled or drawn; the sensory nerve should of course be shown leading to skin cells.

Investigating methods of training. A number of books about pets have been written expressly for young people, and most veterinarians have pamphlets on pet care furnished by pet food manufacturers. Pupils may investigate the stimulus-response mechanism in relation to care and training. Many communities have obedience classes for dogs, and some pupils may have sent their pets to one of these schools. How do such classes get results? How are circus animals or animal actors trained? What makes some persons better trainers than others? Encourage cartoon drawings or other illustrations to accompany reference-reading.

Investigating irritability. If live earthworms are available, place one on a moist sheet of paper. Using a pencil point or a broom straw, investigate response to the stimulus of touch. How will an earthworm respond to light? Encourage children to devise their own investigations. Those who are fishing enthusiasts may be able to give a hint in answer to the question: When is the best time to find earthworms? How does an earthworm respond to pulling? (Its motor nerves stimulate muscle cells to hold the bristles [setae] on the worm's underside so that they oppose a pull.) Pupils may suggest irritability in other animals. Encourage investigation and reports, but stress avoidance of harming the animals.

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. a 4. b 5. a 6. b 7. a 8. a

Using What You Know. 1. The response of getting up became associated with the chores which the boys considered a punishment. A good breakfast, associated with the stimulus of the bell, would have gotten the boys out of bed. 2. The dog cannot understand why he is punished; he therefore associates the punishment with its giver. The bone to chew is a stimulus (a pleasant one) that is substituted for the wood-chewing stimulus.

Section 3: YOU LEARN A "NEW" BEHAVIOR

Pupils examine the usefulness of habits and investigate how they are formed. They begin to understand that insight into a goal plays a role in learning.

Introducing the Concept

What are some things you would like to do if you only had enough time? How many of these things do you know how to do now? Did you learn how to do them? How many would you have to learn to do? For

(Text pages 20-21)

(Text pages 21-32)

SUBCONCEPT

Habits and learning result from interaction of inherited structures with stimuli.

Processes emphasized

Observation
Investigation (with design of experiment)
Insight into problem solving
Discussion
Explaining
Reading
Hypothesizing
Prediction
Reporting
Theorizing

Habits are learned acts that have become automatic.

Equipment and Materials

See text page 25 and also the Teacher's Manual for *Classroom Laboratory 6*.

Past experiences provide insight into methods of solving a problem and achieving a goal.

Equipment and Materials

- ... a ring of assorted keys
- ... a locked box or cabinet
- ... 6 small triangles that will fit together to make a large equilateral triangle

(For the investigation on text page 29, see also the Teacher's Manual for *Classroom Laboratory 6*.)

example, you might like to ride a bicycle or a horse. Are there some things you do that take a lot of time? How could you save time for the things you most want to do? These questions may open up a discussion of the usefulness of learning how to do things as if they were automatic; i.e., the usefulness of habits. Once this discussion is launched, ask: How many habits have you learned? What steps did you have to go through to learn them? It may come as a surprise that getting dressed is a habit or that using a knife and fork is a habit. (The pupil's text discusses only habit formation. Changing of bad habits to good habits is suggested under "Extending the Concept," opposite page.) These questions could be placed on the chalkboard for discussion and investigation:

How did you form the habits you have? How can you form new habits? How do you learn from experience?

Developing the Concept

Unlearned or learned. You blink your eyes, breathe, or sneeze. Did you have to learn to do these acts? (No, they are *inborn*, automatic acts; they are reflexes.) Were you born with the ability to brush your teeth? Tie your shoelaces? Tie a necktie? Do you do these acts automatically? (Yes.) "How come?" as your pupils would say. (You had to learn how.) Recall that a reflex is an automatic act in response to a stimulus. How are brushing teeth and tying a knot different from a reflex? (They had to be learned; they are the result of training.) How did these acts become automatic? (Rewards from parents such as praise; regular practice.) Discuss how reflexes and habits—automatic acts—provide time for other activities; e.g., what if you had to think about everything you do?

The pupils are now ready to read the text up to "Learning About Learning" and to check their hunches about habits by performing the investigation on text page 25. You may initiate planning for the investigation by encouraging the pupils to set down the steps in which they learned to play a musical instrument, ride a bicycle, tie a necktie or pin up their hair, or row a boat. They may also try to dramatize the steps.

Investigations into learning patterns. Prepare in advance and hand out six small triangles, as shown on page T-13. It would be ideal for each pupil to have a set. Can you make one large triangle? After allowing a suitable time for most of the pupils to reach a solution, ask: What was your goal? How did you arrive at it? Now show a key ring with a number of assorted keys and select a volunteer to unlock a box, cabinet, or closet door. How did you finally succeed? By trying or by insight? Allow another volunteer to try. And another—until the pupils see that recognition of size and shape of keys in relation to the keyhole provides *insight* into selecting the few keys, or the only key, that will work. Now read and discuss how Sultan learned to get the banana (text page 26).

Pupils should now plan and carry out the investigation on text page 29. Encourage them to form hypotheses before they perform the investigation and to verify or alter them on the basis of results obtained.

What was needed in all these situations? (A goal and some experience or information.) Can you ever solve a problem without some idea of the answer? (No.) Can you solve a problem without information or experience? (No.) Can you do an investigation in science without knowing what you want to find out? (No.) Can you do it without information? (No.) Where do we get our information? (From others; by talking or reading and by storing what we learn.) This may be a good time to raise a question for the pupils to think about before studying the next section: How do habits help us learn information or how to do something? How can habits hinder us from learning?

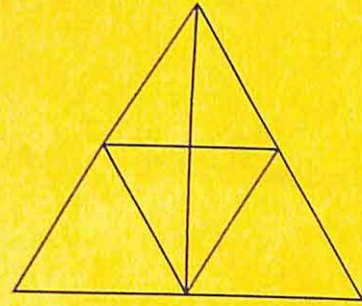
Importance of understanding in learning. Select a sentence, or a couplet from a poem, and write the words one above the other in Column A. In Column B, write the words in jumbled order. Keep both columns covered until you are ready to begin this activity. Uncover Column B and allow about three minutes for memorization. How many succeed? Now uncover Column A. How many succeed in the time allotted? Why? Elicit that understanding of language is important. How does understanding of what is expected apply to training a dog to fetch a ball, for example?

Extending the Concept

How do infants learn? Boys and girls in the class who have baby brothers or sisters may organize a panel discussion. This might include the age at which a baby follows a light with his eyes, reaches for a rattle, lifts a cup by the handle, throws a ball, starts to creep, says a few words, starts to walk. How did he learn to do these things? How many were the result mainly of conditioning? of goal-insight? Do you think the baby has formed habits by the time he is a year old? two years old?

Investigating "flashes" of insight. Perhaps you have heard your father say that he got an idea while he was shaving or your mother an idea while she was cooking. Have you ever tried to do something—ice skate without falling, ride a bicycle, or shoot a basket—and found you could not? Then the next day you were "hot" and had no difficulty. Select some problem or activity you have difficulty with. Plan an attack on it and keep at it. Does a time come when you get a "flash" as to the answer? When did you get it? How long did it take? Devise a way to dramatize your experience for the class.

Can you unlearn a habit? A habit may be good or bad. Why may a habit be a bad one? (It may waste time, make others dislike us, keep us from learning.) How can we change a bad habit? Of course, no pupil should be asked to display bad habits of which he is self-conscious; this activity should be strictly optional after discussion. Not getting up on time, being late to school, talking aloud in class, and similar habits are safe to explore. As many students as wish to participate may select a habit and investigate how they might change it, practice their plan, and



(Text pages 31-32)

SUBCONCEPT

Learning is improved by the development of efficient habits of study.

Processes emphasized

Consulting "experts"
Observation
Analysis
Discussion
Investigation
Hypothesizing
Theorizing
Designing an investigation
Prediction
Inferring from observation
Planning

Achievement of a goal involves insight and requires making of definite plans.

Development of a habit requires practice.

report progress after two or three weeks. Or they may devise an investigation using fish and an aquarium. If the fish are trained to come to the corner of a tank for food when a light is shone on the water, can this response be changed so that they will come for a tap but not for light?

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. a 4. a 5. b

Using What You Know. 1. Pupil's answers. 2. A sample answer might include the pleasure of sharing with another (conditioning) and usefulness in making change (goal-insight) in buying a baseball glove.

Section 4: MAKING LEARNING EASY

Children come to the realization that their growth in knowledge and skills is dependent upon development of good habits of study. These habits are an application of conditioning and insight to a goal.

Introducing the Concept

What do you want to be, or do, when you are grown up? Each pupil at this age can cite a long-term goal, even if it may be unrealistic, and a discussion can be lively. How are you going to get there? You may wish, in advance of beginning this section, to encourage pupils to ask their parents or another relative what employers ask on a job application form or in an interview with a job candidate. Their reports may then show the need of dividing the long-term goal into shorter-term goals related to study habits in school subjects.

What should some of your goals be in school work? How will good habits of study make you more efficient? What are some useful habits to form?

Developing the Concept

Planning helps. On page 32 are five questions. How many of them involve planning? That is, how many of them suggest a goal to be achieved? (All.) What would you state as a goal for each question and why is the goal useful? (For example, a goal for "Do you study each day?" might be, "I plan to study one hour every day" or "I plan to practice each day.") Pupils will note that arrival at a goal involves planning. Do some of the goals require more planning than others? (For example, having a quiet place and the proper tools at hand calls for seeing the process of reaching the goal as well as understanding the goal itself.) What theory of habit formation is chiefly involved in planning? (Goal-insight.)

Practice helps. School records often play an important role in the hiring of persons for special jobs; they also are important if a person wishes to pursue further study in a college. The key word is *study*. What kind of

habits can you develop that will help you study better? What kind of shortcuts in studying will make your study habits more efficient? In order to answer this question, consider the role of conditioning. Can you condition yourself to study the same amount of time each day? What effect will this type of conditioning have on developing study habits? Compare with studying whenever you feel like it. What interests are likely to interfere with studying a regular amount of time? Perhaps you like to play tennis—or some other game that requires skills. How do you become a good player? What relationship is there between studying and a game?

To investigate the importance of practice in habit formation, encourage children to carry out the investigation on text page 33.

The surroundings help. Do you think that tapping on a fish tank, shining a light, and playing a musical instrument, all while you are trying to feed a fish in an aquarium, will train fish to come for food faster? Could you throw a ball as your dog is bringing back another ball and expect him to keep the tasks separate? You can design an experiment to find out, but we can tell you that doing one task at a time gets better results. Can you, for example, study science while a news report is being broadcast over a radio? (Some persons can study efficiently with background music, but conflicting activities tend to cancel each other out.) Pupils can design an investigation into distractions to habit formation by carrying out the memorization of a few stanzas of a poem, as suggested by text page 35. Why does the best studying take place when there is only one stimulus? Encourage children to examine this question in the light of S-R bonding.

Comfortable equipment helps. Suppose you and your friend are going to play tennis or baseball. When you reach the court or the diamond, you find neither of you has brought tennis balls or a baseball glove. Can you practice tennis strokes or knocking up fly balls? What do you need when you are studying? (Obviously, pencil, paper, textbooks, and other equipment, depending on what you are studying.) Can you play tennis when it is getting dark? Can you study without good lighting? Can you write a report without a desk or table to support your pad? If your chair is too low for the table—or too high—can you work well? Or are you uncomfortable? You can design an investigation into how well you study. For example, try studying with improper lighting or wearing an overcoat in a warm room. How do the physical conditions affect your study habits?

Make a floor diagram of where you study at home. Where are the lights? What sources of noise or other distractions are there? Where do you place your books or other tools you may need? Not all of you can have ideal study conditions. Draw up a plan that you think would be good for you. Then plan how nearly you can come to meeting it.

The outcome of a good plan. Planning, practice, surroundings, equipment—these are the needs for developing good study habits, as you have seen. Make a plan of the activities you engage in, or want to engage in, during the day. You will set aside a certain amount of time for dressing, eating, going to school, games, and so on. How much time do you have

Development of a habit requires the proper conditions and surroundings.

Good study habits require the proper tools, equipment, and surroundings.

Pupils infer that development of good study habits results in more efficient learning.

left for study? Most persons complain they never have enough time. How does having a goal save time? How does planning save time? Practice? Surroundings? How are these related to what you have learned about habits? That is, how can you become more efficient? You may wish to consider whether studying with a partner will help both of you learn more quickly or help you learn more in less time. Sometimes this works; sometimes it doesn't. A panel debate on the advantages and disadvantages may reveal interesting questions to explore. Encourage the pupils to make their own plans for more efficient use of study time, letting them have the option of checking with you if they wish.

The pupil's text raises these and other questions. If you have approached this section through discussion first, pupils may now read their text and check their own preliminary thoughts. In any event, encourage relationship of efficient study habits with the theories of conditioning and goal-insight.

Extending the Concept

Approaching a problem. As we learn good habits of study, we learn to save time when a new problem arises. For example, suppose you want to train your dog to heel when you both go out for a walk. Or suppose the leaves of a house plant turn yellow and fall off. What would you do? Would you design an investigation? (No.) Why not? (Before we can arrive at a goal, we need some insight into the way to arrive at the goal.) How can we get insight into the goal quickly? Some individuals follow this procedure by asking themselves these questions:

1. What past experiences are likely to help with the present problem? (Will a reward help in training the dog? Did too much watering cause leaves to fall from another plant?)
2. Have others had experiences that could be helpful? (Dog trainers and nurserymen have experience.)
3. How can I use experiences of others? (After all the facts have been accumulated, it is possible to design a plan and work to carry it out.)

In a year or two of science, you can learn much information that took man a thousand years to discover. We depend on the experience of others. How can we learn what others have learned? (We can read, listen, and observe the work of others.) Select a problem in habit formation about which you would like to know more. How intelligent are animals? (See *How Smart Are Animals*, page T-5). Can animals tell time? (See *Animal Clocks and Compasses*, page T-4.) Report how you found your information and list any questions you may need to find answers to. What kind of plan would you make to find them?

Temperature and work habits. Perhaps you have heard persons say, "I can work better at night than in the morning"—or some other time. Do you feel you can work better at one time than another? Often our temperature changes a half a degree or so below or above normal during the day. Plan an investigation with several of your friends. First, have them

set down the times they think they do their best work. Check oral temperatures upon getting up and at intervals of 3 or 4 hours, until bed time. Is there any relationship between body temperature and time for best work?

Built-in time clocks. Do you wake up regularly at the same time without being called or using an alarm clock? Do you know persons who do? Do you know persons who can judge the time of day with fair accuracy? Can you? How do you explain it—from practice, eating habits, telling time by the sun, or some other way? *Animal Clocks and Compasses* gives interesting information about a “time sense” in animals.

Reviewing the Concept

Before You Go On. Pupils' answers.

Section 5: THE MAIN CONCEPT: CHANGING THE ENVIRONMENT THROUGH LEARNING

The pupils apply the concepts they have been studying in a brief review of the responses of all living things to their surroundings. Among all living things, only man—and perhaps, to a limited extent, a few other animals—has the capacity to react to the environment through goal-insight; that is, man through his heredity has the capacity to learn and to change his environment by applying his knowledge.

CONCEPT SUMMARY

From earlier work in science, the pupils draw from experiences to give them a larger view of how learning will help them adjust to and change their environment intelligently. Since the pupils have some scientific background, you may wish, first, to explore preconceptions through discussion of the questions in the margin, allowing the pupils to attempt to relate and extend the concepts of the unit. Create, if you can, a questioning attitude toward their experiences. Then follow up with close reading for verification, interpretation, generalization, and conceptualization. Encourage formulation of questions for which further observation and data are desirable. If you can begin the development of a questioning attitude, a healthy curiosity, and a desire for learning, the science classroom can become exciting for you and the boys and girls that you have in your charge.

Plants, animals, and climate. Invite discussion of environment and ask for examples. Is the environment of a plant the same as that of an animal? Do different kinds of plants have special environments? Do animals need a special environment? Illustrations attached to the cardboard around which shirts are packaged when they are returned from the laundry can be placed in the chalkboard tray for discussion of specific environments.

(Text page 37)

(Text pages 38–45)

CONCEPTUAL SCHEME

Living things are interdependent with one another and with their environment.

UNIT CONCEPT

Living things are adapted by structure and function to their environment.

Processes emphasized

Observation
Discussion
Analysis of experience
Concept forming
Theorizing
Prediction
Reporting
Categorizing
Inventiveness

What is environment?

Equipment and Materials

... pictures of plants and animals in their habitat

What does interdependence mean?

What does adaptation mean?

What specific adaptations do you have that help you extend the use of the environment beyond that of other living things?

How has your learning improved?

Encourage pupils to aid in the collection of pictures showing unusual environments. Does climate—rainfall, amount of sun, elevation, temperature, and other factors—influence the reactions of plants? Of animals? This review of the pupils' experiences leads into the next question.

The needs of living things. On the basis of your study of living things and their environment, can green plants live without animals? Animals without green plants? What substances does each kind of living thing take from its environment? How do the needs of living things affect their behavior; that is, their responses to the environment? (Plants respond to good soil, sunlight, moisture in their specific habitat; animals respond to conditions and food in their environment.) Are you interdependent with the environment? Give examples. Again, this discussion suggests the next question.

Favorable responses to stimuli. Do all organisms respond equally well to the stimuli of a specific environment? (No.) What examples can you cite? (No polar bears or penguins at the equator; no palm trees in Michigan; azaleas will grow well in acid soil, clover will not.) Do any of these plants or animals change their environment very much? (No.) Why not? (They are adapted by their structure to live in an environment, but they are unable to change it. Therefore, they must live with it or cease to exist.) Is man adapted to his environment? Could he live without processing his food, clothing, and shelter? Can he live in the air or in the water without special aids? This question leads to the next big idea.

Are all organisms equally adapted? What organs enable a fish to live in the water? (Fins and gills.) What organ enables birds and insects to live in the air? (Wings.) Can you spend an hour underwater? Or in the air? (Yes.) What organ enables you to do these things? (The brain.) Other living things have a brain, too. How is your brain different from that of a cat, fish, or chimpanzee? (It is able to store what is learned, and to use the knowledge to make changes in the environment.) A panel discussion might be held on the questions: What *reflexes* (inborn behavior) do you have for adapting to the environment? What *habits* do you have that help you adapt? What *habits* help you change your environment? How does your *brain* help you adapt to many environments?

It is salutary to build a respect for animal adaptations while discussing man's specific adaptations and ability to change the environment. You can sharpen the pupils' perceptions by suggesting they look for animal adaptations superior to those in man, e.g. better teeth, keener eyesight, better hearing, faster motion, stronger limbs, more resistant body covering. How does man compete through his ability to think (goal-insight) and invent? (Saws, telescopes, electronic tubes, airplanes and rockets, machines, clothing, etc.) Encourage careful observation to avoid oversight of obvious adaptations.

Looking ahead. What do you do better now than you did last year? Were these learnings the result of reflexes, conditioning, imitating others, practice, reasoning, or serious planning? This is perhaps a hard question

to answer. Select one thing you do better now. Try to analyze it in terms of the ways persons learn.

Can you learn all by yourself? Only man has a highly developed system of communication by means of which he can share with others what he has learned. Where do your ideas come from? (From reading, discussing, as well as thinking.) For example, in this unit you have studied how an animal's inherited stimulus-response enables it to adapt to the environment. What structures do you have that enable you to keep in touch with your environment? List these in one column. What kinds of activities do these structures enable you to do? (Do not overlook speaking and writing.) List these in a second column. In a third column, check the activities a pet, such as a dog, cat, or turtle, can do in relation to those you have listed in the second column. How do you account for the differences? How much could you learn if you had only reflexes? If you could be only conditioned? If you could only imitate someone else?

Planning for the future. Encourage pupils to consider how they can make the best use of their knowledge of habit formation and environmental conditions to draw up an effective time plan for good learning during their year's work in science. They should include time allotment for study, practice of skills, observation and investigation, seeking explanations, reading, and talking with others—among possible activities. You will probably wish to discuss this plan individually with each pupil as part of your guidance function as a teacher.

FIXING THE MAIN CONCEPTS

Some of the activities depend on individual investigation. Answers cannot generally be provided for these; expected answers, however, are provided for activities that are based on the information in the pupil's textbook. Any phrasing by the pupil that indicates understanding of the concept should be accepted as satisfactory.

Testing Yourself. 1. Offer food each time the bell is rung and at no other time. Caress or compliment the pet. In time, ringing the bell will be sufficient. 2. The dog likes its mistress; her coming out is a *reward* and the dog stops howling. To correct the habit, bring the puppy indoors, give a reward, such as a comfortable bed, and pet it. Do not give it further attention if it howls. It will associate attention with its bed and not with howling. 3. Offer food with the tapping. 4. Goal is to shoot baskets properly; insight is a plan for achieving the goal. 5. Yes. The better student has both a goal and a plan (insight). 6. Good habits save time; good habits make learning easier; good habits improve your grades. Evidence may include regular time for study, good surroundings and the right tools, regular practice, avoidance of distractions. These are involved in good study habits. More efficient study can take place in less time. More time for study can improve grades.

Quick Test. 1. c 2. d 3. b 4. b 5. b 6. d 7. d 8. c 9. b 10. b

(Text pages 42-45)

About This Book

The elephant is stronger than man; but man invents a derrick and a bulldozer to exert more force than an elephant. Man cannot move a mountain, but he builds machinery that can.

Man cannot fly; but, with his brain and hands, man builds airplanes in which he can fly faster than any bird.

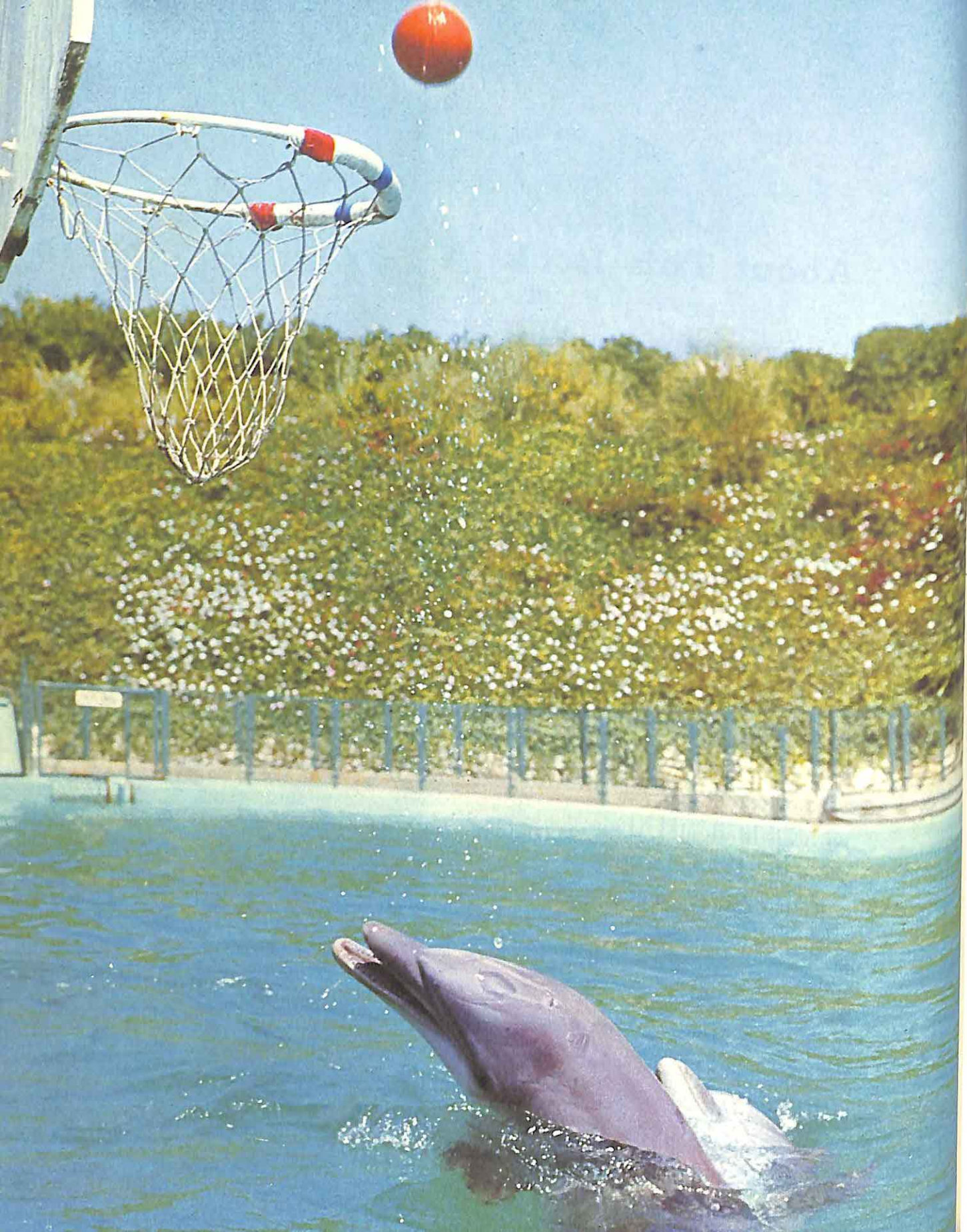
Man cannot live under water; but, with his brain and hands, man builds a nuclear submarine in which he can live under water and travel farther than any fish.

Man cannot swim the ocean; but, with his brain and hands, man builds a ship to take him across.

Man cannot see in the dark; but, with his brain and hands, man has harnessed electricity to light his way at night.

Man can learn; and because he uses his brain and hands, imagination and skill, man can do what no other kind of living thing can do. He thinks and plans and changes the world.





UNIT ONE

LEARNED AND UNLEARNED BEHAVIOR

You are doing a remarkable thing and thinking nothing of it. What do you think it is that you are doing that is so remarkable? No other kind of living thing can do it.

You are reading a book. In doing so, you are using an organ in your body as no other kind of living thing can. That organ is the brain.

Porpoises and other animals can be trained to perform rather complicated acts, and we consider their performances to be remarkable. They cannot compare with man's achievements.

Look around you; read the newspapers; watch television; listen to the radio; and make a list of man's achievements. The list would include: paper, pens, and pencils; bicycles, automobiles, trains, airplanes, rockets, and spaceships; schools, hospitals, and churches; telegraph, telephone, radio, television, and radar; eyeglasses, microscopes, and telescopes; languages, mathematics, poetry, music, and art. All of these are products of the most remarkable of all organs—the human brain.

So man, with his brain and hands, imagination and skill, thinks and acts and changes his environment to satisfy his needs and desires.



1. Perfect—Without Learning

Watch a barn swallow or any other bird build a nest. (Look at the figure marked with the square.) ■ Barn swallows gather mud, plaster it under the eaves of a building or in a barn, and line the nest with feathers. All barn swallows do it, yet they do not have to go to school to learn.

Suppose you could know all your arithmetic, spelling, history, and science, without having to study. Just think how much more you would be able to do.

Yet there are things you can do perfectly from the day you are born. Do you know what they are?

Why not investigate to find out about some of the things you can do

without learning. The investigation on the opposite page is about one of them.

Perfect Performance—From Birth

No matter how hard you or your partner try not to blink, you will blink anyway without thinking about it.

Blinking is an act which you perform without having to learn how. Blinking is an **inborn**, or **unlearned**, act. Sneezing, coughing, and yawning are three other inborn acts.

Take a deep breath, and hold it as long as you can. If you have a watch, check the time. You will find that you cannot hold your breath for long. You cannot stop your heartbeat at all because you cannot control it. You breathe and your heart beats without your having to think. Breathing and the beating of the heart are inborn (unlearned) acts.

Suppose you had to think about and direct the digestion of your food. You would have time for little else. You may think about what you will eat or about chewing it carefully; but, once the food is swallowed, it is digested in the stomach and in the intestines with no more help from you. Digestion is an inborn act.

Simple inborn, or unlearned, acts, such as coughing, blinking, and yawning are known as **reflex acts**. Reflex acts take place without your having to think, and are part of your **behavior** from the time you are born. You can do them quite well without having to learn.

AN INVESTIGATION into the Things You Can Do from Birth

Needed: a partner; a square piece of cellophane; and about six sheets of paper

Crumple the six sheets of paper into six paper balls. ■ Place five where your partner cannot see them, and keep one in your hand.

Then ask your partner to hold the small piece of cellophane in front of his (or her) eyes and to look straight at you. ● Throw the paper ball *gently* against the sheet of cellophane. ▲ Does your partner blink?

Ask your partner to try very hard to keep his eyes open and not to blink, as you throw several more paper balls. Can he do it?

Now exchange and have your partner throw paper balls at you. Try to control your own blinking. Can you?

Did you have to learn how to blink or is blinking an act that can be performed without learning?

Additional Investigation: What other acts can be performed without learning? If there is a new baby in your home, observe his behavior. What unlearned acts does the baby perform?

How do you know the baby's acts are unlearned? When do you think learning begins? Record the first act that you think the baby learned to perform.





Inborn Acts in Animals

You may have watched birds build their nests. Does it seem strange to you that all eastern robins build nests that look alike; or that the nests of all mourning doves are the same? ■ The nests of all Baltimore orioles are alike and so are those of all broad-tailed humming-birds. ● More than that, birds build their nests the very first time they try, without having to learn how. Nest-building is an inborn act in birds, but it is *more* than just a simple reflex act, like blinking.

Some fishes build nests. Their act of nest-building is inborn also. The stickleback, for example, builds a nest of water plants. All sticklebacks build nests and the nests of all sticklebacks look just alike.

Nest-building is inborn; but it is not a simple reflex act such as yawning, coughing, or blinking. When a bird builds a nest, it performs many different acts; so, nest-building is really an unlearned, complicated type of behavior.

Some scientists call complicated, unlearned behavior, such as nest-building, an **instinct**. Perhaps an instinct could be called a series of *complex reflex acts*.

Spinning a web is also a complex reflex act. ▲ It is inborn. Have you watched a spider spin a web? The orange garden spider builds a beautiful one. Can you imagine building such a web without having to learn how? Try to make a copy of a spider's web, using string.

Webs of house spiders are different from those of the garden spider. If you can find the web of a house spider, look at it carefully to see how it is made. The webs are so fine that it is hard to find them until they are covered with dust.

Just as each kind of bird builds its own kind of nest, each kind of spider spins its own kind of web. You may be interested to check this further by finding out how a trap-door spider builds its home.

The important thing to remember is that such acts are inborn. They are fixed behavior patterns.

Some unlearned acts are even more complicated. Have you ever watched a mother cat caring for her kittens?

A group of psychologists (sī-kol'ə-jists), scientists who study behavior, wanted to find out if caring for the young is *really* an unlearned act in certain animals. They took a number of white rats away from their mother as soon as they were born. They kept the baby rats in separate cages, away from all older rats, until they were grown.

When these white rats gave birth to their own young, they cared for them in the same way as any mother rat cares for her young; yet they had never seen it done. ♦ In rats, caring for the young is inborn behavior; but this is not true of all living things.

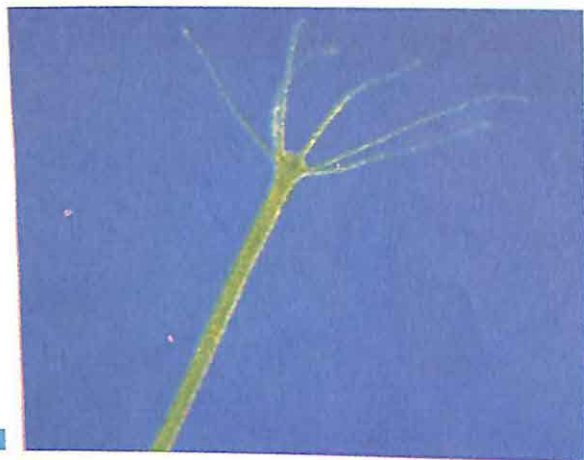
What is it, really, that is inborn? Perhaps there is an explanation in the way the body works. We will use a simple animal to give us our next clue.



Inside the Body ("Message" Relays)

We begin by studying the body of a hydra. A hydra is a tiny animal whose nearest relatives are the jelly-fish. They live in streams and ponds where they hang from the stems of water plants. They are about a quarter of an inch long—and about as thick as a needle.





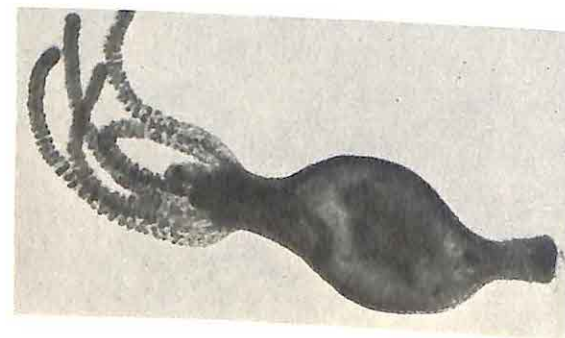
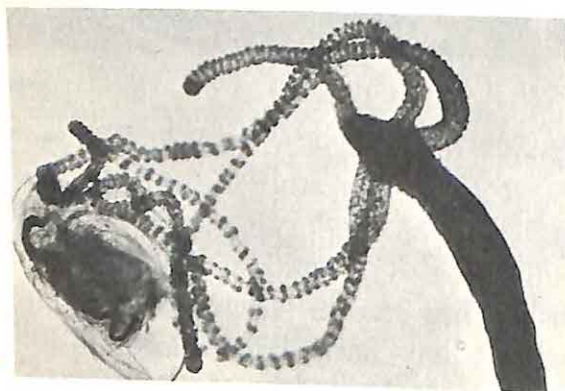
Hydras will grow well in an aquarium, but the aquarium will also need water plants, snails, and even tropical fishes. With a lens you can study the structure and behavior of a hydra. You can watch its **tentacles** (ten'tə-kəls), which seem to be like tiny arms, stretch out in all directions. ■ Hydras feed on small water animals. They can even catch tiny fishes. You may wonder how they do this.

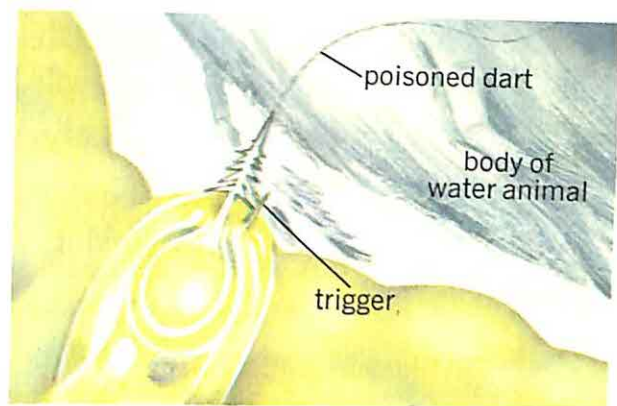
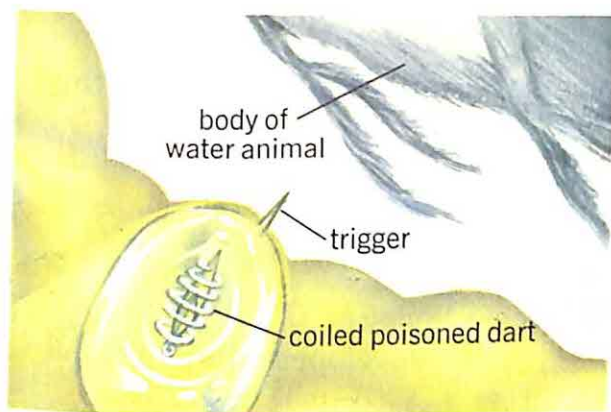
The pictures show a tiny water animal brushing against the tentacles of one of the hydras. The tiny water animal stops suddenly. ● It has been stung by poisonous darts. In the hydra's arms are thousands of tiny poisonous darts, all coiled up, ready to shoot. ▲

When an animal brushes against one of these tentacles, the darts shoot out, and the animal is paralyzed (or anesthetized). Then the tentacles sweep the animal into the hydra's stomach where it is digested. ◆

The poisonous darts shoot out when an animal touches the tiny trigger you see in the picture. ★ ◆ The *touch* of the animal on the trigger of the hydra's tentacles is called a **stimulus** (stim'yə-ləs). A stimulus is anything that results in a **response**, or some kind of activity in a living thing. A stimulus can be one of many things: a touch, a flash of light, something hot or cold or, perhaps, a sound.

Scientists agree that there can be no response without some sort of stimulus. Your eyelids blink *in response* to the stimulus of the thrown paper





ball (page 5). You turn to answer when someone calls your name. The sound of your name is the stimulus which causes a response.

Once an animal brushes against the hydra's tentacles, the muscle cells of the hydra's body respond. They pull the animal into the hydra's stomach. But how does the body "know" that an animal has been caught?

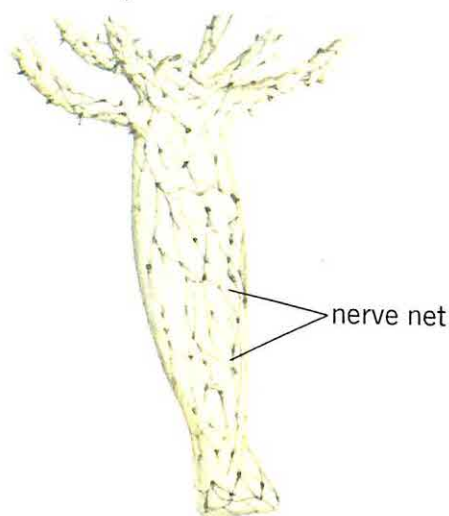
Actually, the hydra does not know what is happening. Its body responds automatically because the "message" is relayed throughout the animal's body by a net of **nerve fibers**. The net of nerve fibers of a hydra extends throughout the animal. A hydra has no real nervous system such as the higher animals have and it has no brain. But even a tiny animal like a hydra has nerve fibers, and nerve fibers carry messages.

We shall call this "message" relay a **nerve impulse**. We are not sure what a nerve impulse is like; but whatever it is, chemical or electrical, that travels along a nerve, it is called a nerve impulse.



Examine the picture of the nerve net of a hydra.⊙ Could you make a model of it? The loose weave in cheesecloth is very much like it. Imagine the body of a hydra with a net of nerve fibers arranged like the weave of cheesecloth. Somehow a *stimulus* starts an *impulse* along the *nerve net* so that the hydra *responds*.

Although the hydra is a simple animal, we still do not know exactly what kind of impulse the nerve net carries. Nerves and nerve nets, and the way they carry impulses, are the objects of much investigation.



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. An example of an unlearned act is
 - a. blinking
 - b. tying a shoelace
2. An unlearned, or reflex, act is
 - a. inborn
 - b. developed after birth
3. The beating of the heart is a
 - a. learned act
 - b. reflex act
4. Nest-building is
 - a. an unlearned act
 - b. a learned act
5. Nest-building is different from blinking in that it is a
 - a. simple reflex act
 - b. complex reflex act
6. In white rats, caring for the young is
 - a. a simple reflex act
 - b. an instinct
7. Nerve impulses in the hydra are carried by a
 - a. nerve net
 - b. stimulus
8. A stimulus brings forth
 - a. another stimulus
 - b. a response
9. A nerve impulse is carried along the nerve. The type of impulse, whether electrical or chemical, is
 - a. known
 - b. unknown
10. The science that is concerned with the way living things behave is called
 - a. psychology
 - b. physics

B. Write a paragraph or two on: Stimulus and Response.

**USING WHAT
YOU KNOW**

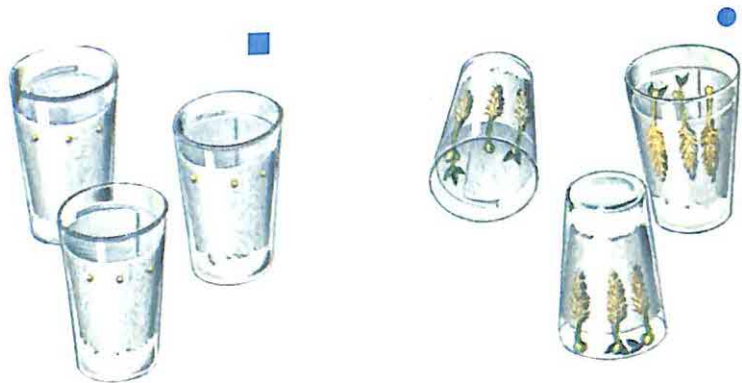
1. Peter's father was an excellent tennis player. In time, Peter came to be captain of his school's tennis team.
The neighbors used to say, "Peter is a born tennis player. After all, like father, like son."

Is tennis-playing an inborn act? What is your reasoning?

2. Jellyfish are relatives of the hydra. What type of nervous system would you expect them to have?

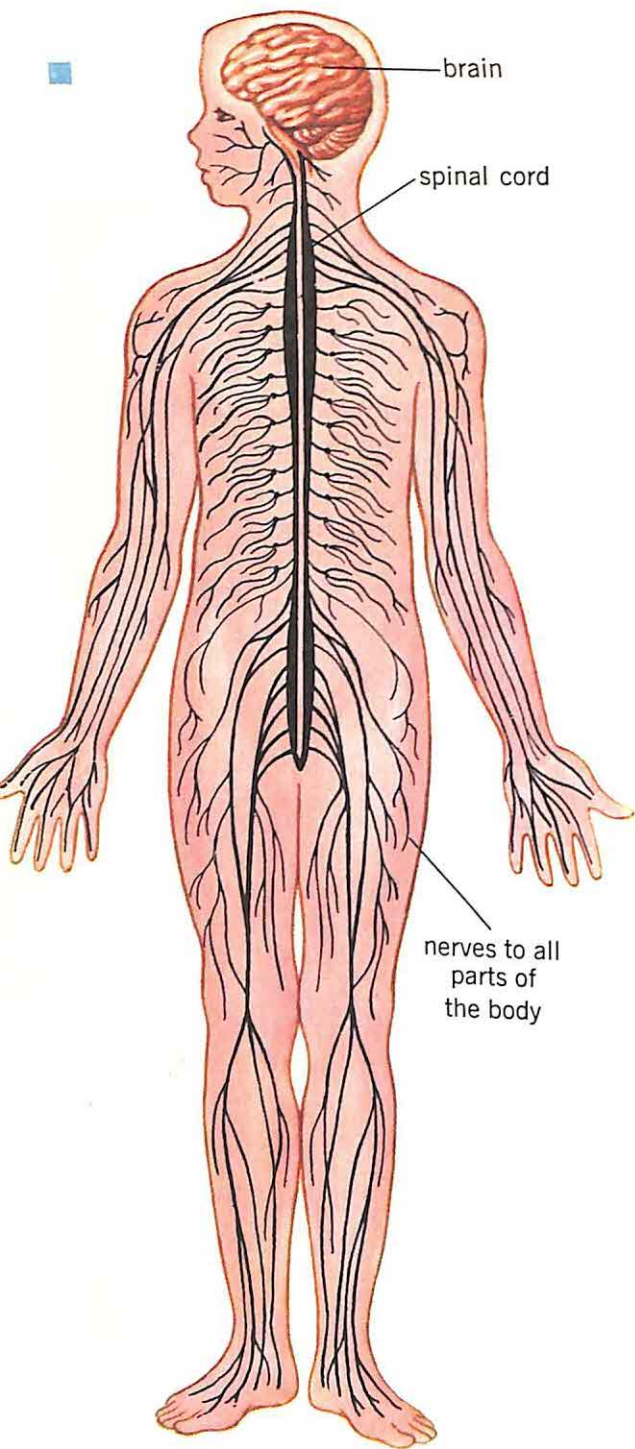
ON YOUR OWN

Do plants have kinds of inborn acts? Try this investigation. Overnight, soak some radish or bean seeds in water. Then line three glass tumblers with blotting paper, as shown in the illustration. ■ Keep some moist cotton at the bottom of each glass. Place at least three seeds between the blotting paper and the glass—about one inch from the rim. When the seedlings have grown above the rim, place one tumbler on its side. Suspend another upside down so that the plants are free to grow. ● Leave the third right side up.



In what direction do the stems of the plants grow? What is your explanation? Can you change their direction of growth?

Scientists call that part of an experiment in which the conditions are unchanged a **control**. In the investigation above, what is the importance of the third tumbler, the one that is standing upright?



2. From the Hydra to Simple Learning

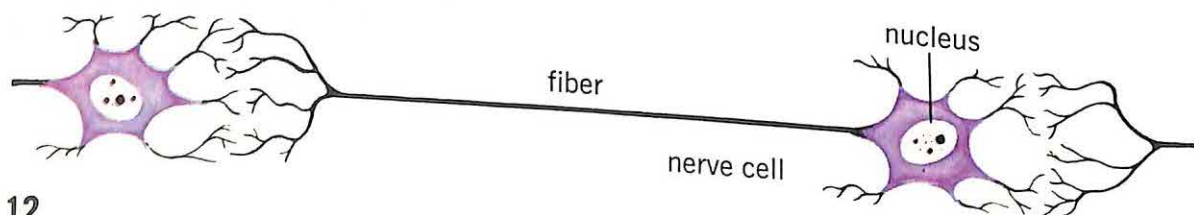
What happens in your body in response to a stimulus? You can observe two of your own reflexes. These reflexes are common to all of us. For a better understanding of them, try the investigation on the opposite page.

Once you have done the investigation, try to explain what happened when the knee was tapped.

A Study of the Nervous System

Your nervous system has nerves that connect with the brain and the spinal cord. (Study the diagram of the nervous system and identify each part.) ■

A nerve is actually made up of many nerve cells. Study the diagram of the nerve cell. ● Notice the long fiber and the way one cell connects with other nerve cells. All nerve cells are connected; however, they are not scattered loosely over the body. The fibers of the nerve cells are in bundles, and the bundles are called nerves. There is, as you can see, a network of nerves throughout your body. If you stub your toe, the stimulus reaches your brain. You respond perhaps by rubbing the toe with your hand. Your toe, head, and hand are connected by nerves.



AN INVESTIGATION into a Common Reflex

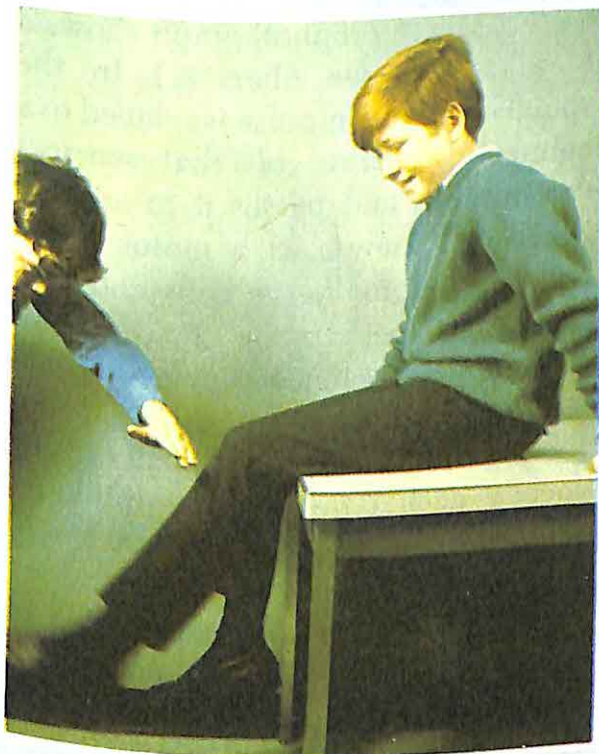
Needed: a small flashlight; a partner

First, ask your partner to sit on the edge of a table. Be certain that the legs hang loosely and that the feet do not touch the floor.

Now ask him to close his eyes. Then, tap him just below the knee with the edge of your palm, as shown in the picture. ■ What happens?

Now it is your turn! Let your partner tap you below the knee. What happens to you? What was the stimulus? What was the response?

Now draw the window blinds or shades, and ask your partner to turn away from the light. Then turn on the

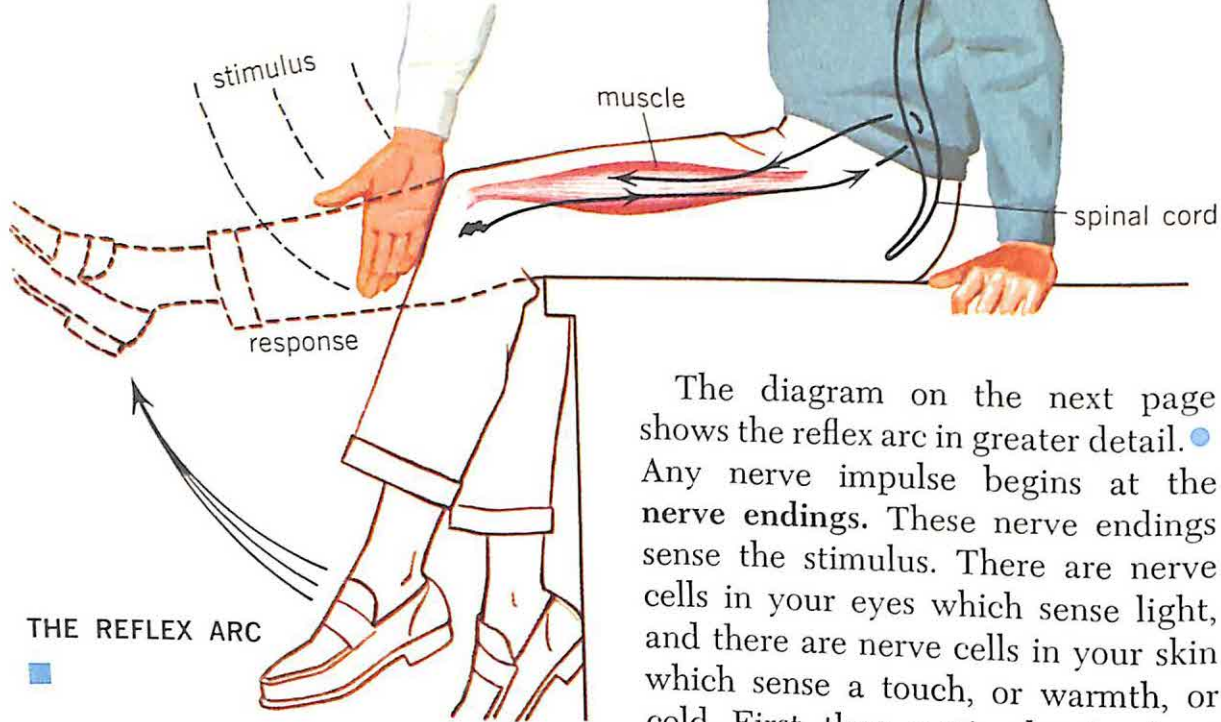


small flashlight, and from the side, flash the light at his eyes. If you use a large flashlight, do not shine the light directly into his eyes. Direct the beam past his head. Observe the pupils of his eyes. What happens? ● ▲

Let your partner observe the same effect on you. What is the stimulus? What is the response?

Here is another important part of this investigation. Ask your partner not to respond to the light. In other words, ask him to control his response.



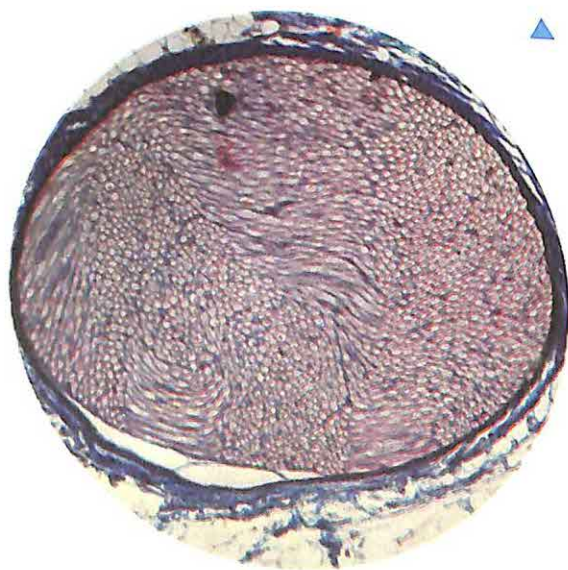


Now trace the path of the stimulus (tap on the knee) in the diagram, all the way to the response (kicking out of the leg). ■ The brain is not involved in the knee reflex, or **reflex arc**. The spinal cord is the place where the nerves seem to be connected.

The diagram on the next page shows the reflex arc in greater detail. ● Any nerve impulse begins at the **nerve endings**. These nerve endings sense the stimulus. There are nerve cells in your eyes which sense light, and there are nerve cells in your skin which sense a touch, or warmth, or cold. First, then, a stimulus (such as the tap on the knee) is *sensed* or received by a cell known as a **sensory nerve cell**.

Second, the sensory nerve cell in the knee has a long nerve fiber which carries the impulse to the spinal cord. (The microphotograph shows a bundle of nerve fibers. ▲) In the spinal cord, the impulse is relayed to a **connecting nerve cell** that *receives* the impulse and passes it to another nerve cell known as a **motor nerve cell**. The motor nerve cells end in a muscle or, perhaps, a gland. When the impulse reaches the leg muscle (as in the case of a tap on the knee), the leg kicks out automatically. Such speedy acts, done without thinking, are part of your behavior from birth.

When your salivary glands produce saliva, an impulse has been carried to the glands by a motor nerve. Of course, in the body many nerve cells take part in any responsive act.



Nerve cells of any kind are called **neurons** (nōōr'ons); so a sensory nerve cell is a sensory neuron; a motor nerve cell is a motor neuron. Scientists think there are at least three kinds of neurons which take part in an inborn, or reflex, act. The fiber of a neuron may vary in length; it may be very short or several feet long.

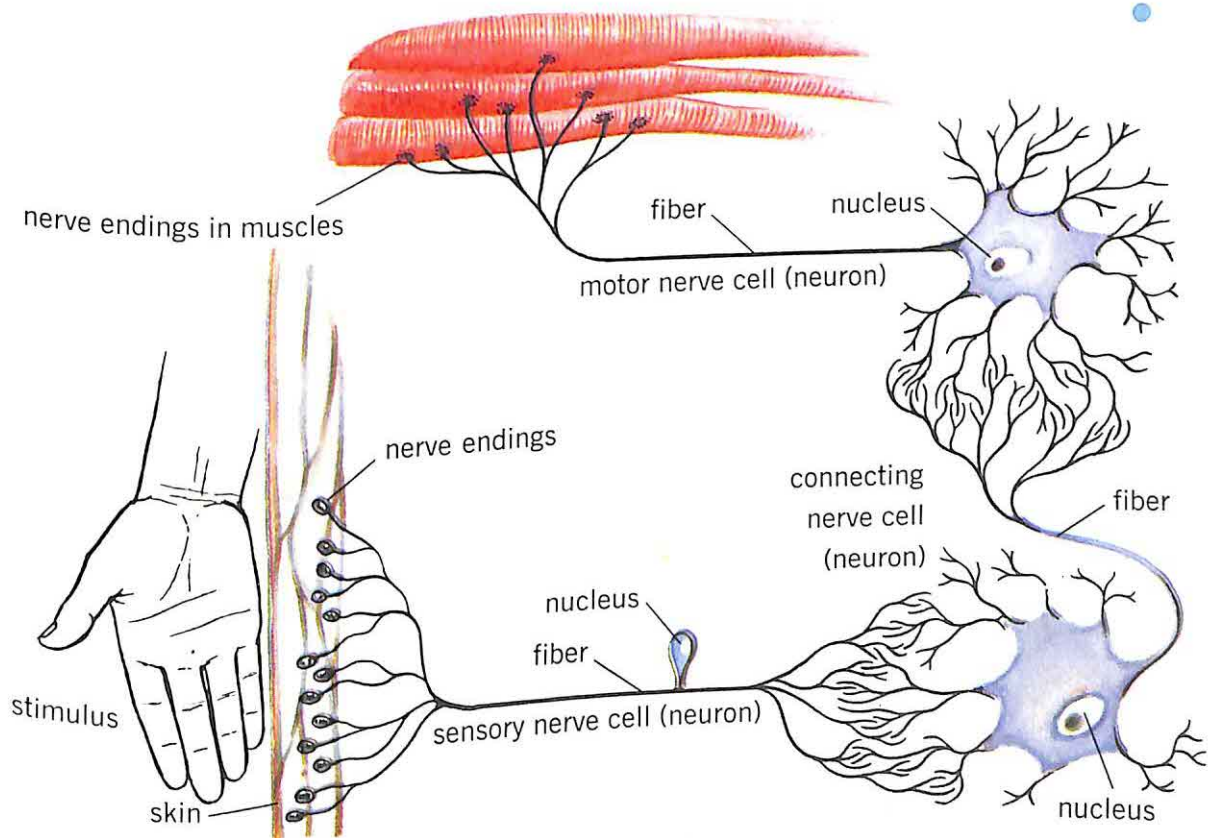
Now, to help you remember, review once again the kinds of neurons that are found in your body. They are:

a. a *sensory neuron*. This nerve cell receives the stimulus, such as the taste of food, and carries a chemical or electrical impulse (or both) to the spinal cord or brain.

b. a *connecting neuron*. This nerve cell connects the sensory neuron with a motor neuron. Connecting neurons are generally found in the spinal cord or brain. A connecting neuron carries the impulse from the sensory neuron to the motor neuron.

c. a *motor neuron*. This nerve cell carries the impulse toward a muscle or gland. That is, motor neurons carry the impulse to the organ which will respond by moving or acting. Recall that your salivary glands respond by forcing saliva into the mouth. Each organ responds in a particular way.

Look again at the diagram of the nerve path of a reflex. Remember that when the spot below the knee is



tapped (a stimulus), the leg kicks out (the response). This act is an inborn, or unlearned, reflex act. For any reflex act, the neurons are already connected and somehow ready to work at birth, but this is by no means the whole story. To learn more about behavior, try to teach a puppy to respond to his name.

Teaching an Animal

A puppy is born with many reflexes. For instance, it has a scratching reflex. ■ If an insect crawls on the puppy, the puppy will scratch. A dog's eyes respond to light. The pupils get smaller in bright light, but widen in the dark. A puppy's heart beats and he breathes, yawns, sneezes, and coughs. All of these are inborn acts; they are reflexes. The neurons which govern these reflex acts are connected at birth and con-



tinue to function as long as the puppy remains alive.

If you have owned a puppy, you may have tried to teach him his name, but it is not likely that he came running to you the first time you called him by name. A response of this sort has to be learned. Responding to the sound of a name is a **learned act**, not a reflex act.

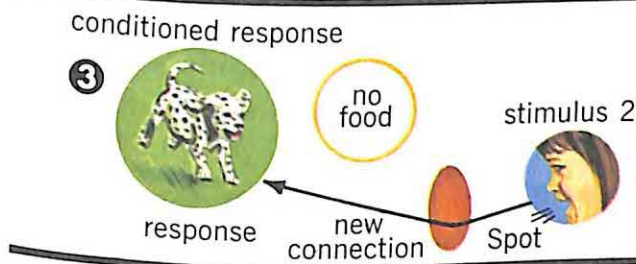
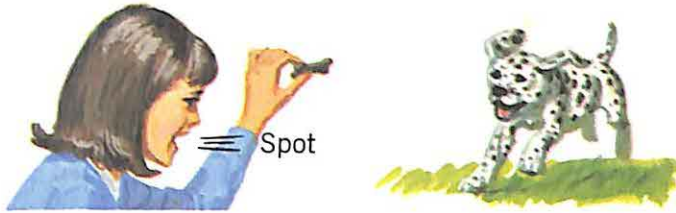
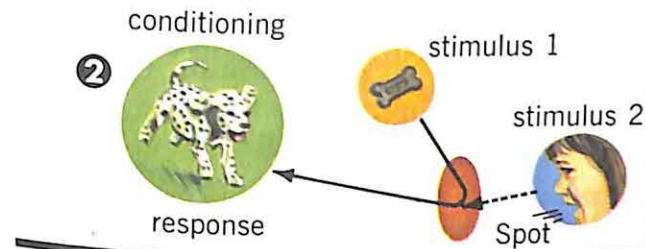
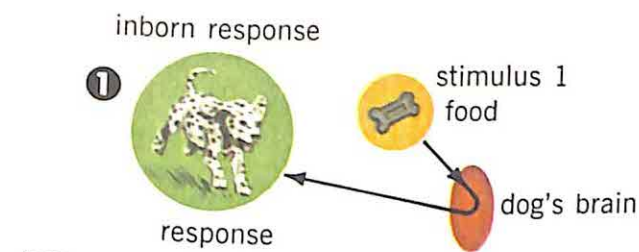
A Learned Act

Suppose you have a Dalmatian puppy, named "Spot." How would you get him to run to you when you call?

You could start by calling his name each time. Animal trainers, however, would tell you that there is a much easier way. They would suggest that you call him Spot when you give him a dog biscuit. Call him by name when you pat his head or when you call him to play. Why does this work?

Why Spot learns his name more easily this way is explained by psychologists as follows: The food, or a pat on the head, is a **reward** that is given at the same time, or just after, the puppy's name is called. Both the stimulus of the food (the reward) and the stimulus of the sound of the puppy's name reach its brain at almost the same time. Somehow they become related, or, as a psychologist would say, **associated**, in the brain. ●

First the puppy responds to the food or to the pat on the head. That is, he responds at first only to the reward; but the *two* stimuli (the *re-*



ward and the *calling of the name*) occur at the same time. Soon the puppy will respond to the name alone. He has learned to respond.

What should you do when the puppy responds to your call of "Spot"? Give him a biscuit the first few times. The next few times, give him a pat on the head. Always reward him when he learns something new until you are sure he has learned. In fact, it is a good idea to give him a pat or reward him some way whenever he pleases you.

One Explanation of Learning

How would you explain a puppy's response to the sound of his name? Do you agree with the following explanation?

A dog gets hungry. Hunger is inborn. You give the puppy food and he eats. Eating and digesting are inborn responses. The puppy responds to the stimulus of food by running to the food. He is happy, or satisfied, when he feeds. Food is his reward. A reward is useful in training any animal.

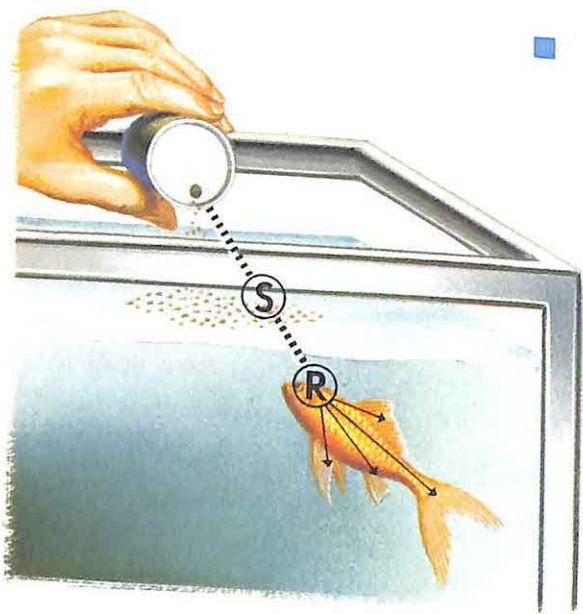
Each time you give the puppy his food, you call him "Spot." Each time he comes to the food, you call his name again. When you call his name, the sound "Spot" is a new stimulus. Somehow the *new* stimulus (sound) is associated with the *old* stimulus (food). The response is the same to both. Study the diagram on this page to help fix this idea in mind. The procedure by which Spot "learned" his name is given on the next page.

a. You would give the puppy something to which he already responds, something he likes. The stimulus of food, for instance, will cause the dog to respond by running to it.

b. You would give him a new stimulus, his name, at the same time you give him the old stimulus, the food.

c. You would repeat this procedure again and again until the dog responds to the new stimulus alone. Then he responds when you call his name, without the stimulus of food. The dog has learned. You have taught him to respond to a new stimulus.

Now that you have an idea how to teach a puppy, can you use a similar idea to teach a fish? Why not try it? Try to train a fish to respond to a flash of light. Do you think it can be done? Plan an investigation into the way a fish can be trained. The first few steps of the investigation are given on the opposite page.



Once you have planned and carried out the investigation, try to explain how you trained the fish to respond to the light of a flashlight.

Scientists have a **theory** to explain this kind of learning and they give their explanation, or theory, a special name. It is called **conditioning** (kən-dish'an-ing). In conditioning, a reward of some kind seems to tie the stimulus and the response together by what is called the **S-R bond** (S, for stimulus and R, for response). In fact, conditioning is sometimes called "S-R bonding." What does the word bonding mean?

Ivan Pavlov, a Russian psychologist, developed the theory of conditioning. Early in the twentieth century, he experimented with dogs in a special way.

Pavlov decided to ring a bell as he gave a dog some food. In other words, the dog was presented with two stimuli at once, food and the sound of a bell. After a few weeks, when the bell was rung, the dog responded to the bell as if he were responding to food. It was as though the dog had acquired a new reflex. Pavlov called the new reflex a *conditioned reflex*.

As you learn more about behavior, you will find that reward or punishment given at the proper time can be very useful in learning.

Pavlov's theory explains how certain reflex acts may be acquired, but it does not explain all about learning. For instance, it does not explain fully the act you may try to learn next.

AN INVESTIGATION into the Training of a Fish

Needed: an aquarium; a flashlight; fish food

Make a plan of the way you would train the fish. You can make use of what you learned about teaching a puppy.

Recall that to train a puppy you should give him a reward when you call him by name. The reward and the sound of his name (the stimuli) are then associated in the brain.

What reward will you give the fish?

What stimulus can be associated with the reward?

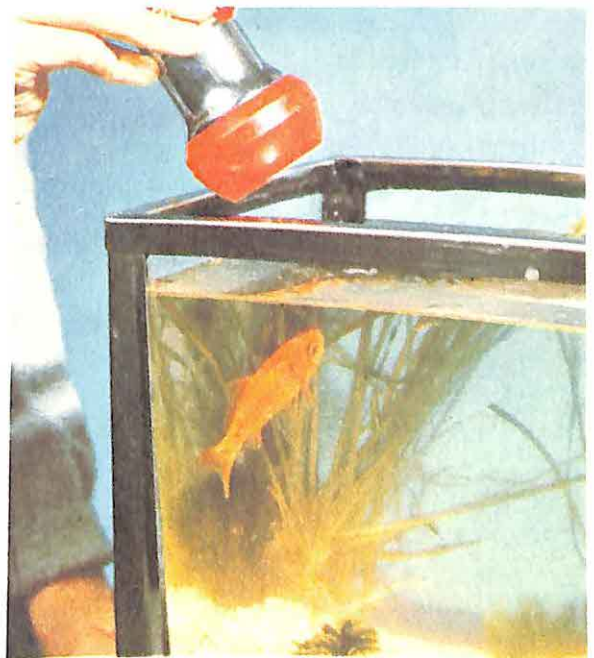
What results do you expect?

Can more than one stimulus be used at the same time?

How long will the response continue if you discontinue the reward?



The pictures show a plan that was used by one class to train their pet goldfish to respond to a flash of light. ■ ● ▲ Perhaps you can think of a better way to train a goldfish. For instance, you might use a bell.



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The central part of your nervous system is the
 - a. brain and spinal cord
 - b. nerve cell
2. A reflex act, such as the knee reflex, takes place
 - a. after thinking
 - b. without thinking
3. A neuron which ends in a muscle or a gland is a
 - a. motor neuron
 - b. sensory neuron
4. The neuron (connecting neuron) which generally connects motor and sensory neurons may be found
 - a. near the muscles
 - b. in the spinal cord
5. The neurons responsible for a reflex act are
 - a. already connected at birth
 - b. developed as you learn
6. Answering to a name is a
 - a. reflex act
 - b. learned act
7. To speed up the act of conditioning, it is useful to associate
 - a. a reward with the act
 - b. punishment with the act
8. S-R bonds help explain
 - a. conditioning
 - b. all learning

B. Write a paragraph or two on this topic: Nerve Cells and the Reflex Act.

**USING WHAT
YOU KNOW**

1. In a camp for boys, one of the older boys was put in charge of a bunkhouse where six other boys lived. He found that it was difficult to get them up in the mornings to do the chores. In order to help them get up on time, he decided to ring a bell.

Once they were awake, he asked the boys to do chores of all kinds—sweeping the bunkhouse, cleaning up, folding their

clothes. Soon the boys did not respond to the bell; some went right back to sleep. Others made believe they were asleep.

What do you think was wrong? How would you correct it?

2. Psychologists sometimes say that a reward is better than punishment in *establishing (conditioning) a habit*. For example, to train (condition) a dog to keep him from biting the furniture, it is often best to give him a real or a rubber bone. Punishment may keep him from biting the furniture, but it may also condition him to dislike the person punishing him. Do you agree? Give your reasons.

There are a good number of books on training pets. What do they have to say on the value of reward or punishment?

3. You Learn a "New" Behavior

Today you may have blinked your eyelids more than 5,000 times. Do you remember each time you blinked?

Today your heart beat thousands of times. Were you aware of your heart beating? You breathed thousands of times. Were you conscious of breathing? You do not think about your heartbeat or your breathing; nor do you think of all the other activities going on inside your body.

Do you remember tying your shoelaces when you put on your shoes this morning? You probably do not remember the details of dressing because you do it without having to think about it.

Whenever you perform an act the same way every time, without thinking, the act is said to be an **automatic**

(ô'tə-mat'ik) **act**. The beating of the heart is an automatic act and so is breathing, blinking, yawning, sneezing, and coughing. All reflexes are automatic; but are all automatic acts reflexes?

Was tying your shoelaces a reflex? Think a moment. Were you able to tie your shoelaces at birth? Of course not. Tying a shoelace is an automatic act, but it is not inborn, or a reflex.

Tying your shoelaces is a simple **habit**. It is something you had to learn. What is the difference then between a reflex and a simple habit?

A reflex is a simple, *unlearned automatic act*. A habit is a *learned automatic act*.

Simple habits are important to you. For one thing, they save you a good deal of time. If you had to think about how to tie your shoelaces each time you put on your shoes, get-



SOME SIMPLE HABITS



ting dressed would take a long time. ■ Then too, a few simple habits, such as brushing your teeth and washing your hands, help keep you in good health. If you brush your teeth every time you eat, that act will become almost automatic—as will washing your hands before you eat.

Certain kinds of habits, such as brushing your teeth, can be explained by the theory of conditioning. For instance, an S-R bond was formed between the stimulus (finishing your meal) and the response (brushing your teeth). The rewards, better health, a pleasant appearance, and the commendation of your parents may have established the S-R bond.

Like some inborn behavior, habits can become very complicated. For instance, spelling correctly or doing arithmetic are *partly* the result of forming good habits, but complicated ones.

You do not have to think when you spell your name or write the word “science” at the top of a paper you hand in; but no one really knows how a person learns to spell the word “science.” No one understands completely how anyone learns to do such complicated things as spelling, or writing, or reading. ● That is, no one really knows as yet how neurons work or how they carry impulses. No one really knows how the brain works or how it “remembers” what it has learned; but the problem is being carefully investigated by many scientists. Some think that the answers lie

in the way the stimulus is connected to the response. Psychologists, however, know that many simple things are learned best through practice.

Forming a Habit

People learn to do all sorts of things as they grow up, and they usually have a reason for learning. One good reason is that learning a habit enables a person to be more efficient. Another reason may be to achieve a reward for learning. The reward may not be something you can see or touch. It may be simply the satisfaction of being able to do something easily. You may not even think of a reward but may learn to do something simply because you want to or have to.

How does one go about learning a simple act? The thing to do is to perform the same act over and over again until it becomes automatic. For instance, you might follow this plan.

First, you have a *goal* to reach. It may be a very simple goal, such as learning to tie your shoelaces.

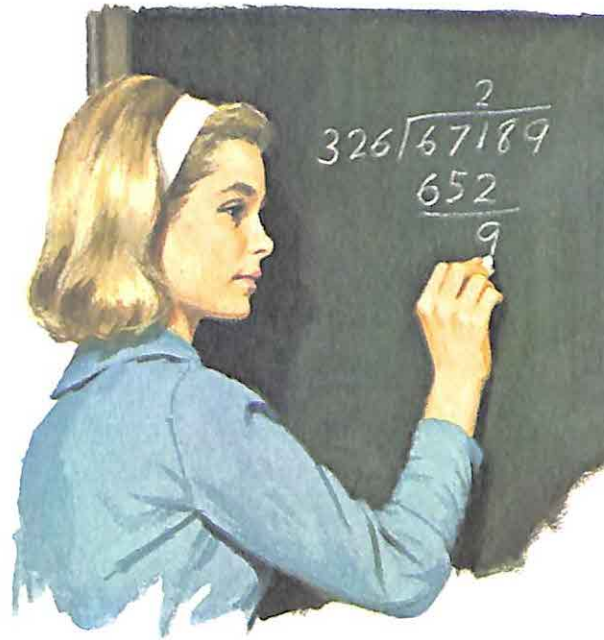
Second, you *plan* how to reach your goal. For example, you may choose to watch someone else tie a shoelace until you are sure of how it is done.

Third, you *practice* over and over what it is you are learning.

Finally, you can perform the act automatically, without thinking about what you are doing.

Do you dream of being able to do something especially well? Would you like to be a champion swimmer or

SOME COMPLICATED HABITS



■ WHAT IS THE REWARD?



diver? an all-star basketball player? Would you like to drive a car? What are your goals? Think about it now, for the earlier you start and the more you learn, the better you will become at whatever you try to do.

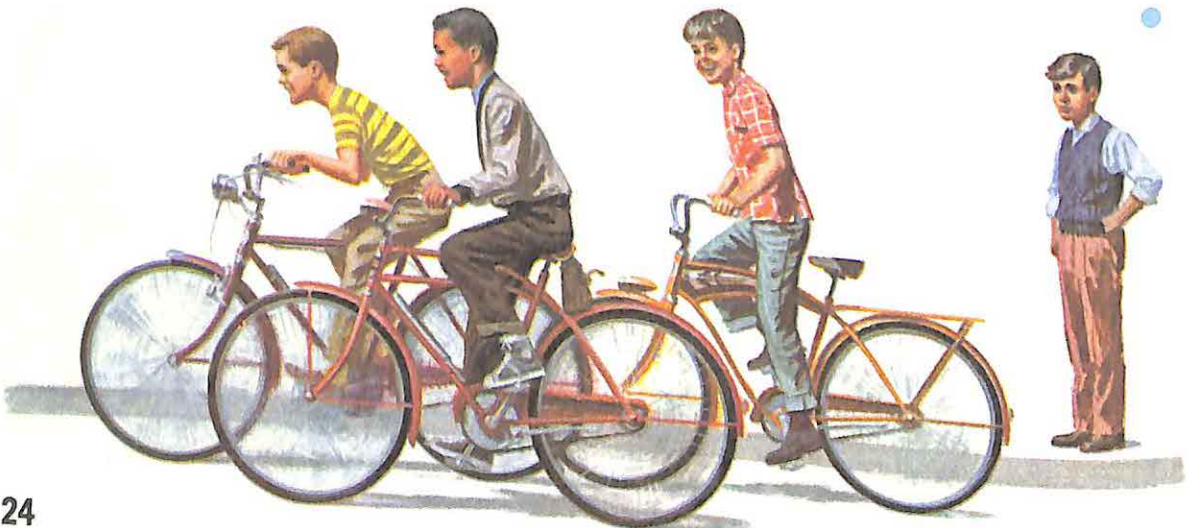
Learning to perform automatically enables a person to be more efficient. Some things you learn to do may also be rewarding. For example:

Why would anyone want to learn to ride a bicycle? What is the re-

ward? ■ Having fun? Getting exercise? Having better health? Being able to have a newspaper route? Helping your parents by running errands? Getting to school easily? Or is there more than one reason?

Why do you think the boy shown standing alone in the picture would want to learn to ride a bicycle? ●

Tying a knot can become a simple habit. Try the investigation on the opposite page to see how long it takes for



AN INVESTIGATION into the Learning of an Automatic Act

Needed: a foot of rope

You can probably tie some kinds of knots, but the kind you will learn to tie here is a special kind.

The pictures show steps in tying a bowline (bō'lin'). ■ It is a very useful knot because it does not slip or become untied.

How fast can you learn to tie the knot? Time yourself. Practice tying the knot until you can do it with your eyes closed. Then compare the time it takes you to learn with the time it takes your classmates. In one class, some of the students learned to tie it faster than others. Some made good tight knots and others made knots that were not so tight. When you can tie a bowline quickly and without wasting time, tying this knot has become a learned automatic act.

Additional Investigation: Plan an investigation to find out if age has any effect on the time it takes to learn to tie a new kind of knot. Do older people learn faster than younger ones?

Extend the investigation to include other acts that may become automatic.



the act to become automatic. You form many simple habits in the same way. Can you explain how the habit was formed?

Brushing your teeth regularly, bathing regularly, and dressing properly are desirable habits. In these instances, the rewards are better health and a pleasing appearance.

Reading, doing arithmetic, spelling, and using the dictionary, all of these are rewarding. Why?

How did you learn to get up at a regular time in the morning? Think back. The reasons may be very complicated, but here is a simple way of looking at this habit and other habits that are like it.

First, you have a goal. Second, you have **insight** into a way of achieving your goal. Third, you practice—until the act becomes a habit.

This manner of learning could be described as the **goal-insight theory**. This theory is based on having a clear goal, insight, and the satisfaction, or reward, of achieving the goal.

Learning About Learning

Up to this point we have studied reflexes and simple habits. We have investigated habit formation, that is, how an act can become automatic. We have investigated how animals learn by conditioning (page 18).

All learning cannot be explained so simply, however. For instance, under what conditions do people learn best? How do we get an “idea”? a “thought”?

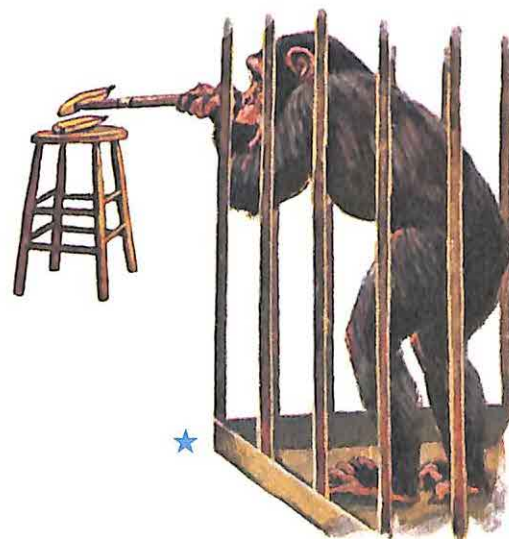
In their attempts to learn about people, scientists often work with animals because they are easier to study than man, especially in the way they learn. Just as rabbits, rats, mice, and guinea pigs have been used in learning how to prevent disease—chimpanzees also have been used to study the learning process. Scientists have learned a great deal from experiments with a chimpanzee by the name of Sultan. They used him in an experiment which tells us something of the way a new idea is developed.

Sultan Gets an “Idea”

Sultan liked bananas, so they were used as a reward in the learning experiment. A banana was put out of Sultan's reach, but a stick was placed near him (as in the picture). ■ Almost at once Sultan used the stick to get the banana. ● Even when the banana was placed out of reach completely, Sultan would try to use the stick. He had learned how to use a tool (the stick) easily. ▲

Then the psychologists tried something different. Sultan was in his cage as usual, but this time a banana was placed outside the cage—just out of reach of his familiar stick. Another stick was put in the cage. The second stick could be joined to Sultan's first stick, as in the picture. ◆ The problem was: Would Sultan learn to fit the sticks together to reach the banana? ★

The scientists doing the experiment reported something like this. First, Sultan tried to reach the banana with



one stick, then with the other. He failed. He walked about, screamed, and chattered. Next, he tried to push one stick with the other stick toward the food. He failed, time after time.

Then suddenly, as if in a flash, he fitted the two sticks together and reached the banana. The idea seemed to come in a "flash." The act seemed to take place immediately.

Because of this investigation, scientists who study learning have come to think that many ideas occur in a "flash." Do they really?

Behind the "Flash"

Do ideas really come out of nowhere? Surely you have had the experience of walking along, or sitting quietly, or reading, or playing—when *suddenly* an "idea" has flashed into your mind.

Recall Sultan's behavior. He had two sticks with which to reach the banana, but they would reach only if they were fitted together. He tried one stick, then the other. He then tried pushing one stick with the other. Finally, with a "flash" of insight he fitted the two sticks together; but remember he had tried other things first *before* he got the "insight."

Somehow he was able to fit his experiences together to form a solution to the problem. The problem: how to reach the banana.

Sultan had needed time to develop insight into solving the problem. During this time he was getting experience by trying different things; and

even though some of his attempts did not work, they gave him an *insight into the solution of the problem*.

Do you learn in the same way when you are trying to solve a problem? Try to find out by doing the investigation on the opposite page.

A "Flash of Insight"—or Not?

Did you solve the problem? How did you get the insight for a solution to the problem?

Does insight come slowly, bit by bit, or suddenly, after time is spent thinking about it? Perhaps it only seems to come suddenly, without thinking.

If it seems to come suddenly, without thought, your "insight" into the problem has put all the parts together, so the solution comes all at once, as if in a "flash." But a good deal of thought is taking place without your knowing about it. The "flash" of insight follows.

Of course, not all problems are solved in a "flash." What information did you need before you could solve the problem? Could you have solved it without knowing

- that 4 ounces is equal to $\frac{1}{2}$ cup?
- how big a measuring cup is?
- that the bottle had just 4 ounces of water in it?

Without information, problems cannot be solved. Without old ideas, new ideas are not so easy to get. In other words, new insights seem to come easier when one has some old ideas to begin with. Insights, or "new ideas," seem to be formed from the

AN INVESTIGATION into a "Problem" in Learning



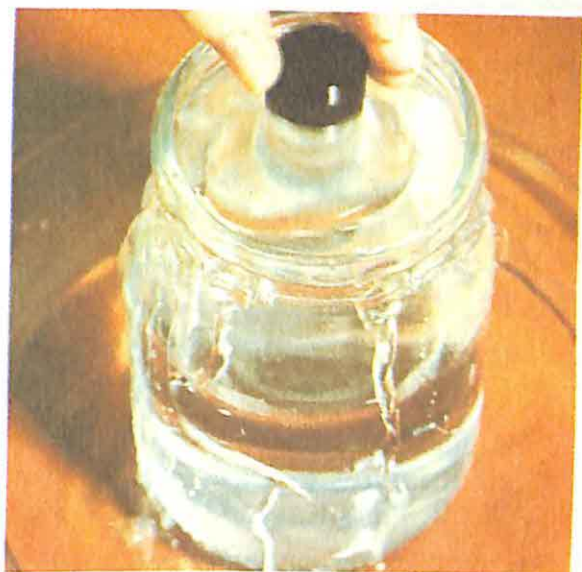
Needed: a quart jar; a measuring cup; a small bottle (4 oz. or under); a pie plate

Suppose you fill the measuring cup to the top line, and then pour out enough water from the measuring cup (perhaps one half) to fill a bottle which will hold 4 ounces.

Suppose the bottle is filled to the brim, then screw on the cap so that the water will not spill out. It is important to know that there would be half a cup of water in the bottle.

Now set the quart jar on the pie plate and fill it right to the top with water, so it is almost ready to overflow. ■

Suppose you were to place the bottle containing the 4 ounces of water into the jar. Be sure to let it drop below the surface of the water. ● About how



much water would flow out of the jar into the pie plate?

Remove the quart jar from the pie plate, empty the measuring cup, and carefully pour the water from the pie plate into the cup. ▲ How full will the cup be?



association of old ideas and information or perhaps from old ideas with new information.

How does this apply to you in your learning of new things? How does it apply to the scientist who is always learning new things?

Theories of Learning

We now have two theories which try to explain how we learn. One is the theory of conditioning and the other is the goal-insight theory.

Some psychologists use the theory of conditioning to explain the learning of simple habits—such as responding to a name or tying a shoelace. They use the goal-insight theory to explain the learning of such complex habits as writing, playing the piano, or memorizing a poem.

As you go on in your study of science, you will have reason to wonder if all our behavior can be explained by the theory of conditioning or the goal-insight theory. You may wonder if we really know how learning takes place. You may find that there is much to be learned about learning.

For instance, you may even begin to wonder if you can trust your own senses. Our senses are very important to the learning process. What we know about the environment comes to us through our senses—taste, sight, smell, touch, and hearing. How good are your senses? Why not investigate? You will need several friends to help.

Take turns blindfolding each other with a large handkerchief and see

how many things you can identify with your sense of touch. Can you tell the difference between a tomato and an apple, a one-dollar bill and a piece of paper the same size and shape?

Can you identify an apple or a tomato by your sense of smell? Can you distinguish the difference between a piece of onion and a piece of apple if you hold your nose while you are tasting them?

See if you can distinguish sounds and the direction from which they come.

From these investigations you may begin to wonder whether your senses can always be trusted. Can they? How do scientists check the accuracy of their observations?

Scientists use instruments to check the accuracy of their observations. They do not trust their senses alone but use instruments to measure what they observe. They do not trust their sense of touch to say how hot or cold something may be; they use a thermometer. They do not trust their sense of sight to determine the intensity of light; they use a light meter. This is true for every observation; they use accurate instruments to check their observations.

Also, scientists check on each other. They repeat observations and experiments many times to verify what they have observed. One trial is never a sufficient basis for drawing a conclusion. Because they know that their senses may be in error, they check and recheck.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Coughing is
 - a. an inborn automatic act
 - b. a learned automatic act
2. Writing is
 - a. an inborn automatic act
 - b. a learned automatic act
3. Simple habits are
 - a. learned automatic acts
 - b. inborn automatic acts
4. The theory of learning by *conditioning* cannot explain acts like
 - a. writing
 - b. tying a shoelace
5. The goal-insight theory is often used to explain the learning of
 - a. simple habits
 - b. complex habits

B. Write a paragraph or two on this topic: How We Learn.

**USING WHAT
YOU KNOW**

1. Look ahead a bit. Try to answer the following questions about your study habits.
 - a. Do you study at home each day?
 - b. Do you begin to do your homework at a regular time each day?
 - c. Do you study in a quiet place?
 - d. Do you have proper tools at hand when you start to study?
 - e. Do you plan what you will study first and what you will study later?

After you read the next section, you will be asked these questions again.

2. In asking people to attempt something new, it is usually best to give them a fairly complete explanation of the reasons *why* they should make such an attempt. Then it seems a good idea to discuss also *how* they might start on the new project.

For instance, your brother or sister or a friend may wonder why it is useful to understand fractions in arithmetic. You might explain *why* it is useful and *how* they could go about learning fractions in school.

Show whether your reasons for learning fractions are explained either by

- a. the theory of conditioning;
- b. the goal-insight theory;
- c. or both.

4. Making Learning Easy

Set this goal for yourself: To master the habit of studying. Recall that you form many habits of doing things automatically, like tying your shoelaces. You can also form habits, such as study habits, which will help you learn better and more easily. As you advance in school, you will study many different subjects, such as English, mathematics, history, social studies, and science. If you learn to study well, you will gain a better understanding of these subjects.

Learning to study well is a complicated habit. Although it takes a long time to form such a habit, there are some things you can begin to do now.

First, you should know the value of having good study habits. In the next six years or so your business will be that of being a student. Just as the father of a family goes to work each day to earn a living, you go to work each day as a student to learn. What you learn will help determine what

you will do all your life. It is important then to become the best student you can—by developing good study habits.

Developing Good Study Habits

Check yourself. In your notebook, write the answers to the five questions which follow. They are concerned with how you study.

1. Do you study each day?
2. Do you study at a regular time each day?
3. Do you study in a quiet place?
4. Do you have proper tools at hand when you study? (Some of the tools you need are: pen, pencils, erasers, ruler, books, paper, a dictionary, and good lighting.)
5. Do you plan what you will study first and what you will study later?

The answers to these questions are important. If you do not answer "yes" to all five of these questions, find out if you should by doing the investigation on the opposite page. Should you change your study habits?

AN INVESTIGATION into How Regular Practice Fixes a Simple Habit

Needed: at least three friends

Ask two of your friends to write their names with their left hand (or with their right if they are left-handed). Ask them to practice on 2 days out of a 5-day week, for about 40 minutes each day; for example, 40 minutes on Tuesday and 40 minutes on Thursday. ■

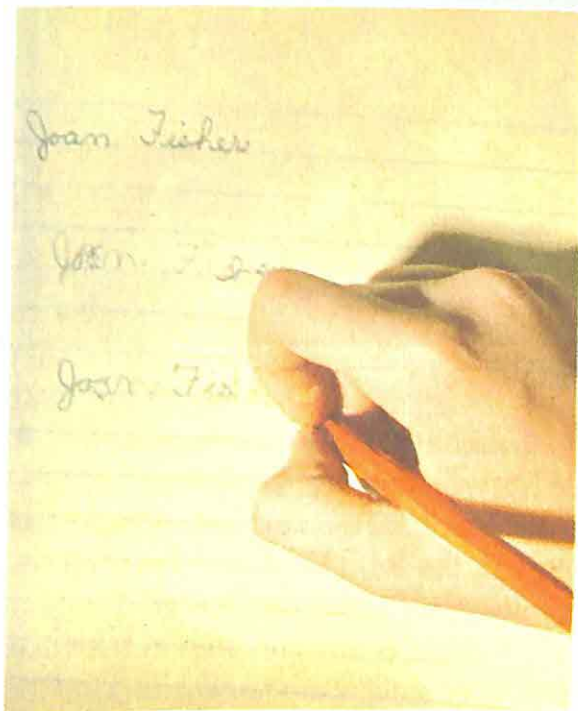
Meanwhile, you and another friend in your class should practice writing your names with the hand not normally used; but you should practice once a day for about 15 minutes each day. ●

After 5 days, who has had the most practice time? At the end of that time the four of you should meet to see who writes better. Were the results for the students who did not practice regularly different from the results of those who did? How would you explain the resulting differences?

Do you agree that regular practice helps fix a habit?

Additional Investigations

1. Does regular practice improve your skill in playing a musical instrument? How do you know?
2. Does regular practice improve skill in your favorite sport? Plan an investigation to find out. Make a progress report.





Look at the pictures above. ■ ● Why will the boy on the right probably learn faster and better than the boy on the left? Which of the pictures shows the way you study? Do you think there is any connection between the way you study and the kind of marks you get in school?

Why should you study each day?

To learn something well you must practice regularly. Regular practice, psychologists have found, helps fix a habit. Thus it is easier to form good study habits by studying an hour every day than by studying several hours one or two days each week.

Why should you study at a regular time each day?

When you were very young, you may have been fed whenever you were hungry. Many small babies do not have a regular time to eat, but even if *you* did not, your family did eat at a regular time. Soon you were eating with your family, and eating

at a regular time became a habit. Do you notice now that you get hungry at lunch time—and at dinner time? Your body is ready for lunch or dinner.

In much the same way, if you plan a regular time for study, you will be ready to start work. Being ready, you will pay more attention to your studying. You will therefore learn better and more easily. Each person selects the study time that is best for him. What time is best for you? Is late at night a good time?

Before you choose the time of day to be used as your study period, think of all the things that might interfere with your being able to concentrate. Then choose a time that would have the least interference. For instance:

Could you concentrate on your lessons when your favorite television program is playing?

Could you concentrate when all your friends are at play?

Choose your study time carefully; it makes studying easier.

Why should you study in a quiet place?

Try this short investigation to help you decide.

Below are 6 stanzas from "The Day Is Done," a poem by Longfellow. Memorize three stanzas in a quiet place. Time yourself.

THE DAY IS DONE

The day is done, and the darkness
Falls from the wings of Night,
As a feather is wafted downward
From an eagle in his flight.

I see the lights of the village
Gleam through the rain and the
mist,
And a feeling of sadness comes o'er
me
That my soul cannot resist:

A feeling of sadness and longing,
That is not akin to pain,
And resembles sorrow only
As the mist resembles the rain.

Come, read to me some poem,
Some simple and heartfelt lay,
That shall soothe this restless feeling,
And banish the thoughts of day.

Not from the grand old masters,
Not from the bards sublime,
Whose distant footsteps echo
Through the corridors of Time.

For, like strains of martial music,
Their mighty thoughts suggest
Life's endless toil and endeavor;
And to-night I long for rest.

Then memorize three more stanzas with the television or the radio on or try to memorize them in a corner of the playground. Time yourself again.

In which place was it easier to memorize: in a quiet place or in a noisy place? How long did it take in either place?

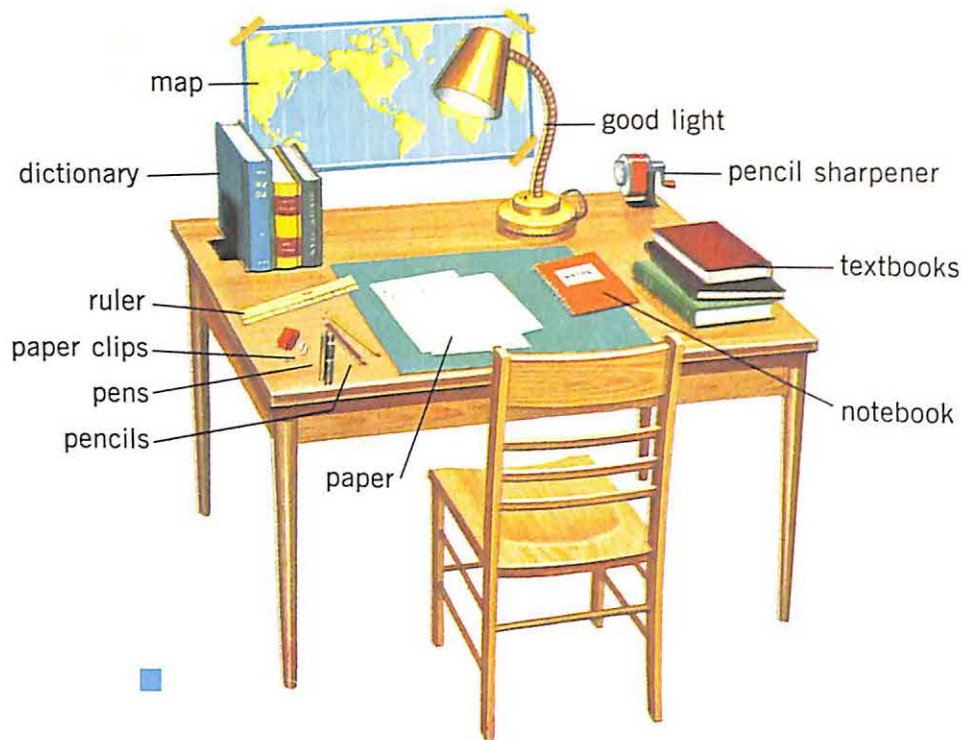
Psychologists have found that it is generally easier for people to study in a quiet place because they can then pay attention more easily to what they are doing.

Do you see why quiet is needed in a library? or in the classroom when you have a reading or a study period?

Why should you have your study tools at hand?

Suppose you were trying to solve an arithmetic problem. Suppose, too, that whenever you needed an eraser or a ruler you had to get up to find one. Not only would this waste time but, more important, you would be taking your attention from the arithmetic problem. Once you give attention to a problem, it is best to keep at it until you finish. You reach a solution sooner. This would allow time for all the other things you may want to be doing at home or at school. It is sensible not to waste time.

In addition to having good study habits, it is important that you should have the proper tools. Before you turn the page, jot down a list of all the items that you think are essential as good study tools. Check with the picture on the next page.



The picture above shows the tools that you need. ■ You should learn how to use them well. For instance, using a dictionary to help you with words you do not know is one important study habit.

Why should you plan what you will study first and what you will study later?

Not everyone finds every subject easy. Some may excel in science and mathematics; others may find English difficult. Suppose you are getting ready to study tomorrow's work. One assignment is in a subject that you find difficult, and another is in one that you find easy.

Would it be best to study the more difficult one first? Psychologists would generally say "yes." It is best to study

the more difficult subject first because you would be studying it when you are physically fresh; you are then more alert. When you have finished studying both subjects, it is well to go over the more difficult one again. This will give you another chance to practice the harder subject and to fix it in mind. It seems that the more you practice a difficult subject, the easier it becomes.

There are other useful things you can learn about the practice of studying. Discuss ways of studying with your friends. Some of them may have successful ways of studying, which you may want to use.

The years spent as a student are very important years of your life. Learn to study well, because learning continues as long as you live.

The scientist must be a good student. Scientists are, in fact, students all their lives. They spend their lives in study and investigation.

Scientists have mastered a special way of learning, that is, through in-

vestigation. They are careful observers and are always looking for the unusual. The uses of ideas and tools in industry is the subject of the next unit. There you will learn more about the ways of the investigator.

BEFORE YOU GO ON

A. First, turn your attention once again to the questions on page 32.

Now that you have read this section, have you begun to improve your own study habits?

1. What exactly have you done to improve your study habits? Make a list of the changes you have made—or the things you have done.

2. How do you plan to study in the future? Make a list of the things you need to do.

B. Write a paragraph or two on this topic: "Habit Formation."

ON YOUR OWN

Look ahead a bit. Investigate the "Art of Investigation." You will find this section in your book on page 409. Since much of your work in science will be in the form of investigation, it is important for you to develop skill in the ways of a scientist. Find out the meaning of the terms "variable" (vâr'ē-ə-bəl) and "control," in relation to an experiment. Review from previous experiences in science what is meant by a hypothesis and what is meant by a theory.

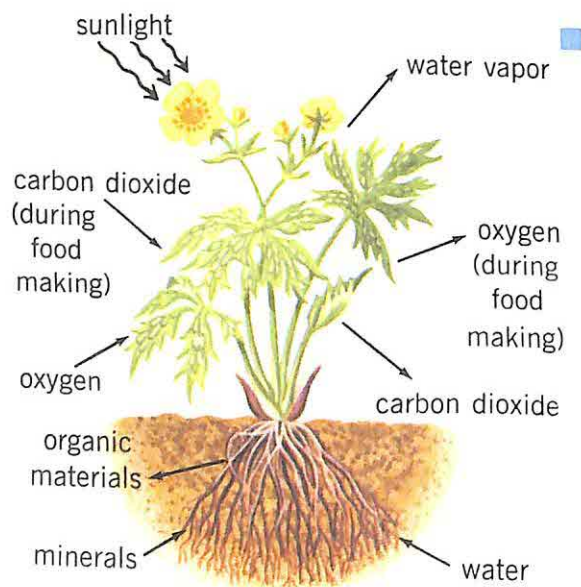
Plan an investigation with a controlled experiment as part of the investigation. For instance, plan an investigation to determine whether or not plants respond to a stimulus such as light. Do they respond to sound? Do they respond to magnetic force? Do they respond to touch? Do they respond to electric currents?

Take your choice of these suggestions or design an investigation yourself. In this case you are truly on your own. You can let your imagination work for you. Be as original as you possibly can.

5. The Main Concept: Changing the Environment Through Learning

Plant a seed in good soil. It can be a bean, or zinnia, or nasturtium seed. Water it. If the seed is planted in a suitable environment, the plant will grow and produce blossoms and more seeds. A bean plant *will not* grow under water, nor on the top of Mount Everest, nor next to a cactus plant on the dry desert. Neither will a zinnia nor a nasturtium plant grow in such places, but some kinds of plants do grow there. Plants are adapted to a *special* environment, a **habitat** (hab'-ə-tat). The habitat for some kinds of plants could be a desert or a mountaintop. For others, the habitat could be the ocean.

The growth of a plant, such as the buttercup shown in the illustration, depends on its surroundings—on a sufficient supply of water, on certain



substances found in the soil, and on sunlight. ■

Plants are a part of and make use of their environment. They change their environment by taking certain substances from it, and by adding others to it. However, the environment in which a bean plant has been growing looks the same after the plant has grown as it did before.

A bean plant, like most plants, does not seem to change its environment greatly, and even then, only temporarily. Plants take substances from the air, the water, and the soil, and they use energy from the sun. In turn, they add, as they decay, the materials that were taken. They also add energy; it is stored in the food plants make. Some of the food may be eaten by animals. The animals use the energy and restore some of the materials to their environment. The rest becomes part of the animal.

The same process is true of animals that is true of plants. Animals need food, water, and shelter; they feed on plants or on other animals; they live in and are part of their environment. ● Ants build nests and mounds; birds build nests; moles burrow through the ground; but these, like other animals, do not seem to change their environment very much, except as they are part of it, coming and going. Animals, like plants, also return to the environment the materials they have used. There is a continuous exchange of matter and energy between living things and their environment.



The inborn unlearned behavior helps an animal to live as a part of its special environment, its habitat. Yet some animals, such as the locust, can destroy crops; and large numbers of mice and rats can do great damage. Still, we usually think of animals as being a part of their environment, not changing it very much.

All living things are adapted to their environment. They also are **interdependent** with their environment. The term interdependent means that living things *take* matter and energy from their environment and *return* matter and energy to it. Interdependence is a major concept of science. Wherever you find living things, you will find them interdependent with their environment.

Man also is adapted to and interdependent with his environment. He uses food, water, and oxygen taken from the environment. He returns the matter in other compounds.

However, in one way man is different. His brain enables him to learn about his environment; but a more important fact is that once he has learned, he is able to change his environment.

Man learns, for example, that all matter is made of atoms and molecules, and he changes the way they are put together. The result is that new substances are created. Man invents nylon, stainless steel, and plastics. He even forms new atoms. Of equal importance, his brain makes it possible for him to record what he has learned—in books, on film, or on tapes with a tape recorder. What he learns, man passes on to others.

A newborn infant lives by his reflexes. Soon, through conditioning, the child learns simple habits and his behavior is changed. For instance, he learns to bathe and to dress himself. Simple habits, however, are not enough. Later, he goes to school and

learns to read and write; these are more complex habits. He also learns mathematics, science, skills in the gymnasium, and how to play baseball or how to dance. ■

Each boy and girl sets his (or her) own goals and develops insight into ways of reaching them. Boys and girls learn to live in a very complex world, one with many different kinds of people as well as many different kinds of machines.

Adults also spend much of their time learning. They are able to *use* much of what they learn in their daily lives in working with others and in earning a living.

Ancient man learned. He learned to build homes from the wood of trees. He learned to get food from plants and animals.

Much later, man began to build farms and cities. He changed his environment; he changed the face of the earth. Man not only lives in his environment, he learns from it. He develops new ideas and invents new devices and changes his environment.

Man, like all living things, is interdependent with his environment; but his ability to acquire new habits through learning makes it possible for him to live in many different environments. In this way, man is unlike any other living thing on earth. Man's creativity gives him a great advantage.

He can live under water but not like fish. He does not have organs which enable him to adapt to a water environment; but he does have an organ which enables him to live in an environment to which he is not adapted.

■ GROWTH IN LEARNING

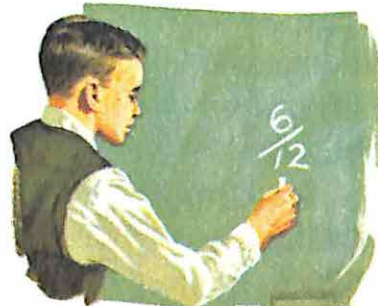
reflexes



conditioned learning



goal-insight learning



That organ is his brain. With his brain he invents a submarine. With his brain he learns new habits which are necessary for him to live successfully in the submarine—under water. With his brain he finds ways to live high in the air, or even in outer space.

Man moves *into* and *out of* many different environments because he is able to learn, to acquire new habits, and to provide for his needs in any environment.

Natural environments change, and animals must adjust to the changes or they cannot survive. Every extinct species became extinct because it could not change or control a new environment. But man can invent new tools, new weapons, and even a whole new environment to suit his fancy. Instead of adjusting to a changing environment, man makes some changes in his environment. This gives man the best chance to survive.

Because man *can* learn, he even changes himself. He learns ways to add years to his life. By changing his diet, he grows taller and healthier.

Man continues to learn. As a scientist, he uses special ways of learning about his environment. The special ways of the scientist are his ways of investigating. • Through these, learning advances at a faster rate than ever before. In fact, the amount of knowledge we are gaining is doubling every 15 years. That is, in 15 years twice as much will be known as is known today. Man hopes that this knowledge will be used for peace.

THE SCIENTIST'S WAY OF INVESTIGATING •



Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts of this unit by doing these problems.

1. Suppose you want your cat—or dog—to eat at a certain time. You decide to use a bell to summon your pet. Describe how you would train your pet to respond to the bell.

2. A new puppy howls at night. The girl to whom the puppy belongs goes outside to quiet it every night for the first week.

However, the puppy continues to howl each night. It stops only when the girl goes outside to quiet it. How do you explain what is happening?

What theory of learning are you using in your explanation?

What would *you* do to change the puppy's behavior? Why do you think your method would work?

3. How would you train a fish to come to the side of a glass tank which you tapped?

4. A boy is learning to play basketball. Somehow, his shot at the basket hits the rim most of the time. He gets very discouraged and asks the coach to help him.

The coach of the team knows that the way the boy stands as he throws the ball is causing him to miss the basket. The coach takes him aside and asks him to watch a boy who "shoots baskets" well. In particular, the boy is asked to watch the other boy's feet as he takes his shot.

Use the goal-insight theory of learning to explain what you think the coach is doing.

5. Teachers know that often the difference in learning ability between two boys is not their intelligence level. They know that one boy has better study habits than the other.

From what you know about different students, do you think this is possible?

6. Which of the following statements are correct? Give evidence or reasons for your choice.

Good study habits save time.

Good study habits waste time.

Good study habits make learning easier.

Good study habits improve your grades.

Good study habits make no difference.

QUICK TEST

Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this unit.

1. Of the following, only one is not an inborn automatic act. That one is

a. coughing

b. sneezing

c. reading

d. yawning

2. Of the following, only one is not an inborn automatic act. That one is a

a. spider spinning a web

b. robin building a nest

c. moth flying toward a light

d. baby saying "daddy"

3. Of the following, the neuron which carries the impulse to the muscle is the

a. sensory neuron

b. motor neuron

c. connecting neuron

d. sensory nerve ending

4. The scientist who developed the theory of conditioning is

a. Salk

b. Pavlov

c. Freud

d. Darwin

5. It is thought that a reward fixes the behavior where a new response takes the place of the original response. For instance, a dog that responded only to food now responds to the sound of his name. This act is explained by the

a. fact that it is an inborn act

b. theory of conditioning

c. fact that it is an instinct

d. theory of goal-insight

6. A boy realizes the usefulness of saving money for something he wants to buy. This act is explained in terms of
- reflexes
 - instincts
 - the theory of conditioning
 - the goal-insight theory
7. Man can learn better than any other living thing because of his
- neurons
 - nerves
 - senses
 - brain
8. Practice is essential to the development of
- an inborn automatic act
 - a reflex
 - a habit
 - an instinct
9. The first acts of a baby are
- habits
 - reflexes
 - learned acts
 - learned automatic acts
10. As man grows up he gradually acquires
- more reflexes
 - more habits
 - fewer reflexes
 - fewer habits

FOR YOUR READING

1. *Story of People*, by May Edel, published by Little, Brown, Boston, 1953.

This book is a good account of the behaviors of different groups of people. Customs and habits are described.

2. *The Friendly Phoebe*, by Berta and Elmer Hader, published by The Macmillan Co., New York, 1953.

This is a story of a newly hatched phoebe and the way it was cared for until it was able to care for itself. In the story is an interesting account of the reflexes and learning ability of a phoebe.

3. *The Senses of Animals and Men*, by Lorus J. and Margery Milne, published by Atheneum, 1962.

This book is an introduction to the five basic senses.

ON YOUR OWN

The inborn automatic acts of some plants are called *tropisms* (trō'piz-əms).

For instance, stems of plants always seem to grow toward the light. If the action is movement or growth *toward* the stimulus, we say the tropistic response is *positive*. So growth of a plant toward light is a positive tropism. Growth away from a stimulus is called a negative tropism.

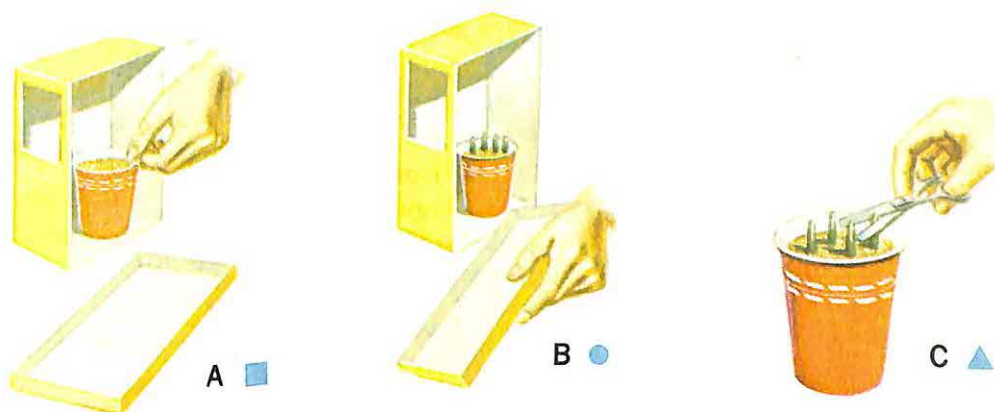
An Investigation into the Behavior of a Plant

Get some oat seed or corn. Plant four seeds in sand in a paper cup. Place each seed about one-half inch below the surface. Keep the sand moist, but to be sure that the sand is not too moist, punch holes in the bottom of the paper cup.

Just as soon as the tips of the plant poke through the surface, place the plants in a shoe box, as shown. ■ Notice the window cut in the box. Then close the cover.

After a few days the plants should look like those in the picture. ● Now repeat this with two or three more cups of seeds, except for one difference. When the seeds have grown about one inch, use scissors to snip off the tips of two of the four seedlings in each cup. ▲ Leave two plants with their tips whole. Place the cups in the shoe box once again.

1. What do you observe?
2. Do your observations agree with others in your class?
3. How do you explain your observations?
4. Invent a theory which will help to explain your observations. Recall that a theory is an explanation of observations.



CONCEPTUAL SCHEME

Living things are interdependent with one another and with their environment.

Unit Two

IDEAS AND TOOLS: FOR NEW PRODUCTS

UNIT CONCEPT

Living things are adapted by structure and function to their environment.

The brain is man's greatest structure for adaptation. Man uses it to investigate his environment and then to formulate concepts to explain objects and events. With these concepts as working ideas he then invents tools for control of the physical environment. In this unit, pupils gain understanding of important relationships between science and technology, between the processes of the investigator and the products of the inventor.

A VIEW OF THE UNIT

This unit places in historical perspective man's search to explain his world and to invent a technology to control it. The unit is closely related to Unit One since it shows how processes of learning are similar to the scientist's processes of investigation. As early man tried to seek reasonable and testable explanations, he began to gain insight into ways he could control his environment. That is, he used his brain to ask himself questions, to develop hypotheses, to design investigations, and to formulate concepts by which he could investigate still other questions.

Among the first and most important products of technology are the metals. They easily illustrate the partnership of science and technology. As pupils begin their study of the first section, it may come as a surprise to them that aluminum was not available in any quantity until three quarters of a century ago. They are introduced to some of the problems that both scientists and inventors had to solve. Concepts dealing with the structure and behavior of matter, with the nature of heat, and with the energy of moving electrons were among those that had to be understood. Furthermore, tools had to be invented. Science and invention went hand in hand—but very slowly at first.

The textbook purposely does not develop all the concepts involved in the technology of the extraction of aluminum from its ore. Some are too complex for understanding at this level. However, an occasional pupil may ask a perceptive question that is difficult to answer. For example, both Hall's process for obtaining aluminum and the pupil's investigation into freeing copper from a copper sulfate solution (text pages 50–51) in-

A Preview of the Concepts

Technology of Metals

volve a type of solution called an *electrolyte*, which is capable of conducting electricity. You may need to decide whether to attempt a short explanation or refer the interested student to the subject of ionization in a high school textbook.

Briefly—and incompletely—a metal salt such as copper sulfate forms in solution into particles (copper ions) with a positive charge and particles with a negative charge (sulfate ions). As you note, these particles are called *ions*. A wire attached to the negative terminal of a dry cell will have a negative charge and a wire attached to the positive terminal will have a positive charge. When these wires are placed in the copper sulfate electrolyte, there is a complete circuit through which electrons flow. As electrons flow from the negative terminal (*cathode*), positive copper ions are attracted to the cathode, lose their charge, and are deposited (plate out) as metallic copper without a charge. Much the same process takes place when an electric current is passed through aluminum oxide dissolved in molten cryolite. The solution is the electrolyte, and aluminum ions are attracted to the cathode where they gather as pure, uncharged aluminum atoms. Current electricity will be studied in Unit Six, but understanding of the nature of electricity is not immediately essential to understanding the process of obtaining metals from their ore.

Hall's process required great heat as well as electric current. Extraction of many metals from their ores requires heat. This is especially true of copper and iron, which the pupils will study in Section 3. Section 2 therefore explores the Kinetic Theory of Heat, or the nature of the transfer of heat energy from molecule to molecule in a substance. Armed with this concept, pupils trace the history of man's discovery and uses of copper and iron. He learned much about metals through trial and error, but it was not until he began to understand and use the processes of science that he could invent new tools and new products such as the alloys that are so useful today. The concept that matter consists of atoms became a powerful new tool for technological advances only in recent times. Science and technology are now close partners.

In Section 4, the concept of the structure of matter is related to the molecular structure of fibers built by living things and applied to the technology of artificial fibers.

Throughout the unit, the important concept developed is that man, through the use of his brain, has extended his interdependence with his environment by finding new ways to interchange matter and energy with the environment. Processes of science lead to the products of technology.

SUPPLEMENTARY AIDS

Names and addresses of distributors and suppliers of films and filmstrips are on page F-26. All the films and filmstrips are in color.

Archaeologists at Work (13 min.), F.A. Archaeologists help us learn about people and the lives they led in prehistoric past. (Intermediate)

Technology of Fibers

Films

Filmstrips

Evidence for Molecules and Atoms (19 min.), E.B.F. Demonstrates that, though unseen, molecules and atoms can be proved to exist in solids, liquids, and gases. Modern science is based on the existence of atoms and molecules.
(Intermediate)

Explaining Matter, Chemical Change (11 min.), E.B.F. A chemical change takes place when atoms from the molecules of two or more substances join with one another to form molecules of entirely different substances.
(Intermediate)

Explaining Matter: Molecules in Motion (11 min.), E.B.F. Molecular motion determines the properties of each state—solid, liquid, or gas. (Intermediate)

Louis Pasteur (50 frames), E.B.F. Color drawings tell us of his experiments with microbes; how they cause disease; how animals and men inoculated with these germs become immune.
(Junior High)

Man in Space (47 frames), S.V.E. Shows how scientists have been able to develop an environment for space travel; how they have met problems of weightlessness, acceleration, temperature extremes, radiation, and nourishment of space travelers. Shows training necessary to become an astronaut.
(Junior High)

Earth—A Great Storehouse (44 frames), S.V.E., 1962. Shows the great variety of minerals found in earth's crust; how man mines for these minerals and the uses he makes of them.
(Intermediate)

Man's Preparation for Space Travel (35 frames), Jam Handy. Explains the problems that must be solved before man can travel in space; how scientists are able to solve these problems; differences between travel in the atmosphere and in outer space.
(Junior High)

Addresses of the publishers are given on page F-24. Starred (°) titles are especially recommended for content and reading level.

°*Albert Einstein: Young Thinker* by Marie Hammontree, Bobbs-Merrill, 1961. Einstein's boyhood, his schooling and interests, and final recognition as a great scientist are described. The personality of this great man, as well as his achievements, are displayed throughout the story.
(Easy)

All About Fire by Raymond Holden, Random House, 1964. Explains essential uses of fire by man, and advances that have been made in fire-fighting. Describes fire as man's friend and enemy, from prehistoric times until today. A chapter "Fire from the Sun" describes the production of energy in the form of heat.
(Average)

Breakthroughs in Science by Isaac Asimov, Houghton Mifflin, 1959. The lives and discoveries of great scientists from Archimedes to Goddard are described. In all, twenty-six short stories narrate the greatest scientific breakthroughs of historical time.
(Average)

The Cave Hunters by William E. Scheele, World Publishing, 1959. Describes two kinds of hunters, Neanderthals and Cro-Magnons, who roamed over Europe before the end of the last great Ice Age. The story of what probably

Science Reading Table

happened when these hunters met as civilization began to dawn is based on present scientific knowledge. (Average)

**The Caves of the Great Hunters* by Hans Baumann, Pantheon Books (a division of Random House), 1962. A story of the prehistoric caves and of the discovery of the famous cave of Lascaux, known as the "Louvre of Prehistoric Caves." Color photographs enhance the realism of the accidental discovery of these famous prehistoric sites and art treasures by four boys and a dog. (Average)

The Crazy Cantilever and Other Science Experiments by Robert R. Kadesch, Harper & Row, 1961. Forty experiments designed to help the investigator not only to acquire information but to enjoy the process. All are in the area of physical science. The experiments may be performed in any order: each is a self-contained unit. (Average)

Explorations in Science: A Book of Basic Experiments by Harry Milgrom, Dutton, 1961. Simple but challenging experiments to help pupils understand basic principles of physical science. The 27 experiments are clearly described and illustrated with more than 100 diagrams. (Average)

The First Men in the World (paperback) by Anne Terry White, Scholastic Book Services, A Division of Scholastic Magazines, 1961, published by arrangement with Random House. A story that spans a million years. The clues about early man—stone hatchets, cave paintings, skeletons of prehistoric beasts and prehistoric man—are puzzling pieces added together with much study. An account of true facts that reads like fiction. (Average)

Further Explorations in Science: A Second Book of Basic Experiments by Harry Milgrom, Dutton, 1963. Challenges the reader to investigate many areas of science; with 20 experiments. Only simple and easily obtained materials are required. The experimenter is made familiar with the workings of the seismograph, the hygrometer, and the barometer. (Average)

**Rock Oil to Rockets* by Dirk Gringhuis, Macmillan, 1960. The story of petroleum in America. Includes description of the discovery, uses, and refining of oil; and the progress in energy supply from the first drilling to rocket engines. Graphically illustrated in color and black-and-white. (Easy)

The Story of Dams by Peter Farb, Harvey House, 1961. An introduction of hydrology, including not only the engineering of the dams, but also the water cycle, flood control, and other phases of the problems of water supply for man's survival. Contains a guide to the location of more than two hundred dams in the United States. (Advanced)

**The Story of Madame Curie* (paperback) by Alice Thorne, Scholastic Book Services, A Division of Scholastic Magazines, 1961, published by arrangement with Grosset & Dunlap. From her school days in Poland to life as a wife, mother, and scientist in Paris, this story depicts the struggles and successes of one of the world's greatest women. An informational story of the discovery of radium, as well as biography. (Easy)

What Is Matter? by Daniel Q. Posin, Benefic Press, 1962. A compact survey of the characteristics, behavior, and potential of matter. Numerous illustrations

help to describe solids, liquids, gases, nuclear change in matter, anti-matter, and matter as frozen energy. Includes a simplified description of Einstein's formula for figuring the amount of energy that may be released from matter. (Advanced)

► INTRODUCING THE UNIT

Pupils perhaps have heard their elders speak of the "good old days." Ask: What do you have today that your grandparents did not have when they were your age? What changes have taken place? Which are the results of the work of scientists or inventors? Can you have inventions without scientists? Pupils might, instead, prefer to imagine that Lincoln were alive today. What terms would Lincoln hear on television or read in newspapers that would be unfamiliar to him? (For example, space travel, television, supersonic jets, cryogenics, etc.) What changes would he see in the nation's capital (or any other city)? Which result from the work of scientists or inventors? Can you have inventions without scientists?

(Text pages 48-56)

SUBCONCEPT

Substances (minerals) in the earth's crust can be altered to produce new materials.

Processes emphasized

Investigation
Observation
Analysis of reading
Discussion
Library research
Gathering of data
Mapmaking
Consulting experts
Hypothesizing
Categorizing

Discovery of new processes and products depends on understanding concepts in science, as well as earlier technological advances.

Section 1: CHARLES HALL AND HIS DISCOVERY

As an example of how man used ideas and tools, the pupils investigate the obtaining of useful elements from common compounds. Charles Hall's method of extracting aluminum from a clay shows how a concept was tested and applied.

Introducing the Concept

Write on the board the caption METALS IN YOUR LIFE. Ask: How often do you use metals in school? At home? What kinds of metals do you depend on daily? The metals which are suggested might be listed on the board. Pupils should be encouraged to state where these metals come from. Do they occur naturally in this form? Of course, most do not. How do we get them then?

Hold up a handful of clay soil. Do you think you could get a metal from it? Suggest that the pupils look for an answer to this question:

What parts of an airplane or rocket come from clay?

Developing the Concept

How do you find out? In your work in science you have considered many questions and have met many problems. You have looked for answers to why, what, how, when, and where. Your method of finding answers has been *Investigation*. Why was there almost no aluminum until after 1886? Refer children to the text, page 48, to find out how and why Charles Hall discovered how to extract aluminum from its ore. What concept did Hall have to have before he could make his discovery? (The concept that elements join chemically to form compounds, and that com-

pounds may be separated into their elements.) Was Hall's a new concept or was it an invention based on concepts developed by other scientists? (The latter.)

Separating a metal from its compounds. The components of a compound are usually strongly bound together chemically. Some form of energy must be supplied to break the chemical bonds and separate these components from the compounds. The energy used may be heat, electric current, or chemical reaction.

Pupils should already know the difference between physical and chemical changes, but it may be useful to review briefly.

Chemical change—a change in matter in which atoms of substances combine or separate to form new molecules (compounds). The properties of the final products differ from the properties of the original substances.

Physical change—a change in matter that does not alter its chemical composition. The properties of the substances changed are the same as those of the original substances, although size, shape, and state of the substances may be changed.

Unit Two, "About 100 Building Blocks," in *Concepts in Science 5*, is a useful reference for review of elements and compounds if the pupils are unsure of the meaning of the term *chemically combined*.

Invite a few pupils to plan and perform the investigation into electroplating with copper (text pages 50–51). You may wish to emphasize that "it is not easy" to separate aluminum from its oxide or compound; hence, copper sulfate, which dissolves readily in water and "plates out" with a dry cell as the source of electric energy, is used in the investigation showing how a pure metal may be separated from a compound. After discussion, link the "discovery" of copper, which the pupils have made, to the discovery made by Hall. What steps in the two processes are similar? How did Hall make the idea of energy from electric current work for him? The pupils will have noted that the copper is deposited on one coin only and that changing the connections on the dry cells reversed the action. The copper is attracted to one terminal (see page T-21). Hall had to find something that would dissolve aluminum oxide; cryolite—a compound of sodium, aluminum, and fluorine—is a powerful solvent, when molten, for many minerals. He used electricity as his source of energy. In actual commercial recovery, steel bars are embedded in the bottom of a carbon-lined tank, since carbon is resistant to cryolite. Electric current passing through the bars and the solution keeps the solution molten at about 1,800° F., and aluminum is attracted from its oxide to the bottom of the tank, much as copper was attracted to the coin in the investigation.

What are the uses of aluminum? Pupils will enjoy investigating the many uses of aluminum. Initiate discussion by inquiring about the advantageous properties of aluminum. Then list them on the board. (Light-

*Energy is needed to separate
als from their compounds.*

Equipment and Materials
See text page 50; also
Teacher's Manual for *Classroom
Laboratory 6*.

Aluminum has many uses.

Invention of new materials depends on understanding basic concepts of science.

ness, strength, doesn't rust through.) Relate these advantages to the uses we make of aluminum. A few questions may help to stimulate thought. Why is aluminum a good metal for building airplanes? Why is aluminum sometimes used in making pots and pans for cooking, or on the outside of homes? Why are boats made of aluminum? How is aluminum used in the home, on the farm, and in industry? The key to its use, of course, is that the oxide of aluminum is hard and protects the metal it covers.

How concepts in science are used. How do the terms *pure science* and *applied science* differ? How are they dependent on each other? Relate to the investigations you have done this year or in earlier courses in science. How does the scientist get his concepts? (By observations—and careful planning of investigations.) How do you build your concepts in science? (By observation through investigation.) How does the development of concepts lead to invention of new materials? Can scientists and technology really be separated? Encourage the pupils, as part of the discussion, to invent new devices and support their invention with one or more concepts. Interested students should be urged to develop investigations to support their "hunches."

Extending the Concept

Where are metallic ores found? What sources of metals are there in your area? Pupils may wish to extend this activity by constructing a map showing where in the United States different metallic ores are found. If a large map is drawn for the bulletin board, samples of these ores may be taped to the map to indicate their correct location, or displayed on a table with strings leading to the map location. What ores are other countries noted for? A similar map of metallic ores could be made for those countries which the children are studying this year in geography.

Metals, minerals, and elements. How does a metal and a mineral differ? Volunteers can consult references and report to the class. Standard encyclopedias for elementary grades are useful. Metals usually occur in mineral compounds called ores, mined from the ground or extracted from the water of the earth. How do metals and elements differ? (Elements include metals.)

Research laboratories. Industries spend millions of dollars each year for chemical laboratories and salaries for personnel. Why do most industries consider research so important?

Pupils' parents engaged as researchers or chemists for a local industry may serve as useful resource persons. Also, solicit the help of industries in your area in explaining the type of research in which they are involved. How does research help in the production of new and better products?

Beginnings of an industry. How and in what country was aluminum first used industrially? The pupils will be interested to learn that aluminum was produced by other processes 60 years before Hall developed his simple and inexpensive way of obtaining aluminum in quantity.

One of the first aluminum products was a rattle for the infant son of the French Emperor, Napoleon III. Later, Napoleon III had a set of forks and spoons made to use when serving honored guests. In 1885 the French scientist Deville, who had developed a process of obtaining aluminum, was given a commission to outfit the French army with aluminum equipment. One advantage of aluminum over other metals then used was its lightness. However, Deville's process of extracting aluminum was too expensive to outfit an army. How has the process of extracting pure aluminum been refined?

The top of the Washington monument was one of the first aluminum structures in the United States. What was one of the advantages of topping this structure with aluminum? (It wouldn't tarnish.)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. a 4. b

Using What You Know. Both. The scientists attempt to develop concepts or modifications of them, which the technologist applies in designing a rocket. If an idea doesn't work, scientists and technologists try to find an answer.

Section 2: USES OF A CONCEPT

Pupils discover that molecules in all substances are constantly in motion. Their motion is determined by their energy. The faster molecules move, the greater their heat energy.

Introducing the Concept

One introduction might be to play a game of "Let's suppose," applying it to the phenomenon of heat in the third paragraph. If, suddenly, there were no sunlight, why would air turn to liquid and then to a solid? All pupils know that the sun is the source of radiant energy. When its rays fall upon objects, they become warm. Why? (The sun's energy makes molecules move faster. The radiant energy is changed to energy of motion—that is, to heat energy.) What examples can you give of heat causing a physical change in a substance? (Melting, evaporation—also, condensation and turning to a solid if heat is withdrawn.)

What is heat (energy)? What concept concerning the behavior of molecules helps us understand heat? How is this concept useful to us in explaining a simple tool such as the thermometer? How do we use this knowledge in controlling our environment?

Developing the Concept

Investigating heat. Two groups of several pupils may perform the investigations on text pages 58 and 59. Check for these understandings as the questions following the investigations are discussed.

(Text page 56)

(Text pages 57–67)

SUBCONCEPT

Knowledge of the nature of heat has enabled man to develop ways to modify and control his environment.

Processes emphasized

Investigation (with design of experiment)
Observation
Measurement
Hypothesizing
Theorizing
Prediction
Planning an investigation (with control experiment)
Analysis of devices
Concept forming

When a substance becomes warmer, the motion of its molecules increases.

Equipment and Materials

See text pages 58 and 59; also the Teacher's Manual for Classroom Laboratory 6.

Heat is the kinetic energy of molecules.

Heat is transferred from one place to another by moving molecules.

Molecules of matter are in constant motion.

Heat is the energy of moving molecules. The faster the molecules move, the greater the heat.

Heat energy is transferred.

In carrying out the first investigation, plain glass jars or tumblers may be substituted for beakers, provided water that is very hot is poured in gradually. The use of a stopwatch might intensify concern for accuracy in timing the operations.

For the second investigation, an empty glass bottle may be more convenient than the flask, provided you have a one-hole stopper and plastic tubing to fit. You will want to show the children how wetting the tube will make its insertion into the stopper easier. Challenge the children to think of the advantage of wetting the tube. (Reduction of friction.)

The energy of molecules in motion. Refer pupils to "The Nature of Heat," text page 62, which introduces the term *kinetic energy*. What does this term mean? Does a rock on a cliff have kinetic energy? A waterfall? A jumping horse? A parked automobile? A can of gasoline? Boiling water? How do you know? The rock is not moving, but the water is. The horse is certainly in motion. Neither the gasoline nor the automobile is in motion, but put the gasoline in the tank, turn on the ignition, put the car in gear, and the car moves. The hood also gets hot, so something in the gasoline is in motion then. The boiling water is escaping into the air as water vapor. Clearly water molecules and gasoline molecules in motion have energy. What is kinetic energy? (Simply, the energy of matter in motion.) Encourage pupils to cite other examples of kinetic energy. Is at least some of the energy heat energy? What molecules are in motion? While you are sitting still, do you have kinetic heat energy? (Lay a hand on your bare arm. It feels warm for much the same reason a radio feels warm when it is running or an auto hood feels warm right after a drive.) What other things can you cite that feel warm or hot when their molecules are moving rapidly?

Heat energy is transferred. From the "Investigation into the Nature of Heat," pupils found that the warmer a liquid becomes, the higher it will rise in the tube. As the liquid cools, the column will fall. Pupils can apply their understanding of the transfer of heat energy by investigating the rise and fall of a liquid in a thermometer. The pupils should be clear that the *molecules* of a substance do not expand or contract; they merely move farther apart, causing the substance to seek to occupy a greater volume.

Secure two or more household wall thermometers. Check to be sure that all read the same at room temperature. Record the room temperature on the board. Make a record of readings in different parts of the classroom. Many children know that air is cooler near the floor than near the ceiling. They can verify this by planning an investigation. How do the thermometers show that heat energy at different levels is being transferred? Children might also investigate, on the school grounds, the transfer of the sun's energy in exposed and shady places.

Molecules in a vacuum. How do certain materials help keep heat in as well as keep heat out? To stimulate discussion you may wish to emphasize this statement from the text: "There is a shortage of moving molecules in a vacuum." The conduction of heat depends on molecules colliding with one another. In a partial vacuum there are few molecules. A vacuum is thus a good insulator, as indicated by the investigation (text page 59).

Exhibit a vacuum bottle. Do you think it can keep hot things hot and cold things cold? How does it work? Of what purpose is the vacuum space in the bottle? (The vacuum space does not conduct heat in or out, there are few molecules of air in it.) Children will enjoy reporting on other insulated objects and how they work. For example, how does a refrigerator work? a stove? the insulation in the walls or ceiling of a home?

Hot or cold? Pupils often think of hotness and coldness as two different conditions. Ask, in summary: How can you use the kinetic theory of heat to explain how you can make an object cooler? (By removing its kinetic energy; that is, by slowing down its molecules. For example, ice takes heat from a hot drink; the heat energy is transferred.) How can you keep an object hot (or cold)? (By preventing transfer of heat; that is, by insulation.)

Extending the Concept

A display of insulating materials. Challenge pupils to plan a display of insulating materials. Discuss how each material works. Does it keep heat in? Does it keep heat out? What use is made of this material?

If parents of pupils are building constructors, architects, electrical engineers, or heating and air conditioning experts, invite them to share experiences of working with insulated materials.

Molecules without motion. An inquisitive pupil may ask if it is possible for molecules to have no motion; that is, no heat energy. It is possible, theoretically, for heat to be removed from a substance until its molecules have no motion. Absolute zero, the temperature at which an object could be wholly without heat energy, is about 459.7° F. below zero. Cooling systems for scientific studies have been devised which operate within a fractional degree above absolute zero. In practice, certain substances at this low temperature have different properties. Interested pupils may be referred to cryogenics, the science that applies the principle of cooling to very low temperatures.

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. b 4. a 5. a 6. b 7. a 8. a 9. a 10. b

Using What You Know. 1. The scientist develops the concept that certain substances, when they combine chemically, change their properties. He may, in his investigations, discover a promising avenue of attack on the blow-out

Heat energy is transferred from molecule to molecule; it cannot be transferred in a vacuum.

A substance becomes cooler as a result of transfer of its heat energy.

(Text pages 65-67)

problem. The technologist may take over the job and refine the process with new tools he invents. 2. It would probably be a solid, be very dense, occupy little space, and weigh more for its volume than the same substance at a higher temperature.

(Text pages 68–84)

SUBCONCEPT

Metals can be separated from their compounds; they can be combined to obtain new compounds having new properties.

Processes emphasized

Analysis of technological development
Discussion
Hypothesizing
Investigation
Observation
Analysis of evidence
Theorizing
Library research
Concept forming
Analysis of data
Categorizing
Organizing data

Section 3: THE USES OF IDEAS AND TOOLS: NEW METALS

Pupils begin to appreciate more fully how concepts are developed and used in the invention of tools for technological improvement. They see how the processes of discovery and advances in scientific knowledge have given us methods of separating metals from their ores and of combining substances to obtain new metals with improved properties.

Introducing the Concept

There are several ways to introduce the concept. If the pupils in social studies have investigated Indian life or early cultures in other lands, you may find it useful to relate technological developments to changes in cultures. For example, which tribes of American Indians were food-gatherers? (The Plains Indians; the coastal tribes, such as the acorn harvesters; the woodland tribes—all food-gatherers or hunters.) Which tribes were food-producers? (The Southwest Pueblo Indians, and many tribes of the Middle Atlantic regions.) Which tribes were more advanced in the use of tools? (The builders and cultivators.)

Or—which do you think came first in ancient times, an understanding of how things work or the tools to work with? Do people invent tools first or do they first investigate, as you have been doing in science for the last several years? That is, when does inventing begin, and how does it come about? (The concepts of learning from Unit One give a clue to the discussion.)

Or—you probably know now that the science you know and the materials and tools you use are based on ideas others before you have had and on inventions they have made. Why do you think the American Indians (or any type of early man) lived in tents, caves, or wooden huts and did not build skyscrapers; used wooden hoes and not tractors; or rode on horses and not in automobiles?

In whatever way you introduce the concept, the important point is that the pupils be encouraged to think about which came first, the invention of a tool or the concept that explains its use. Encourage them to think of the concepts that must have been acquired and the inventions that ensued.

As soon as discussion lags, the pupils may read through “An Ancient Fire and a Great Discovery,” trying to find answers to these questions:

How did man make his first discoveries about materials in his environment? How did he use these discoveries? What makes man change from old ways of doing things to new ways?

Developing the Concept

Copper—probably the first-used metal. Review the question: What is an ore? Recall that Charles Martin Hall obtained aluminum from its ore, aluminum oxide (bauxite). In the investigation in Section 1, the pupils themselves obtained pure copper by using an electric current. Hall, also, used electricity. Copper was first discovered 8 to 10 thousand years ago. What source of energy was used to obtain copper from its ore? (Heat.) Why was heat—and not electricity—used? Initiate discussion leading to understanding that means of controlling heat had been invented, but that the concept of electricity had not even been thought of. You can't get aluminum from aluminum oxide by using heat only. Can we get copper from heating copper oxide with just a Bunsen burner? The pupils hypothesize and then are encouraged to set up the "Investigation into Getting a Metal from Its Compound" (text page 72). Oxygen must be freed from the oxide. If the additional investigation is performed, using malachite, the gas given off is carbon dioxide.

What concept does the investigation illustrate? (Heat energy can change a solid compound into a liquid or a gas—or both; the gas will be driven off.) Did the early discoverers know this concept? (No.) Why not? (They had only insufficient evidence; all they knew was that heat gave them copper from certain kinds of rocks. This they must have learned by slow trial and error.) Pupils may now read up to "Furnaces for Making Iron" (text page 77), considering the steps in learning that the earlier discoverers of copper are likely to have gone through.

Getting iron from its ore. Could you get along without iron? What differences in your life would there be if iron had not been discovered? Although iron ore is abundant in the earth's crust, it took early man several thousand years after discovering the use of heat to obtain copper (until about 3000 B.C.), to learn how to smelt iron. You know that it is difficult to separate metals from their chemical partners. From your knowledge of oxides from Section 1 of this unit (or from *Concepts in Science 5*, Unit Two), what hypothesis can you make about obtaining iron from rocks; that is, from an iron oxide ore? Why was early man unable even to make this hypothesis? (Men had found copper free in the earth, but iron exists almost entirely as an oxide.) Pupils may now read up to "Advancing the Technology of Steel," text page 78.

Why does iron exist chiefly as an oxide? Pupils should be able to hypothesize the readiness with which oxygen combines chemically with iron. They verify the hypothesis by performing the "Investigation into How Fast a Tin Can Rusts" (text page 81).

Understanding the why and how of discovery. What knowledge did early man not have that made the technology of metals so slow? What concepts do you already have about metals that early man did not have? List the ideas on the chalkboard as they are suggested. For example: Each metal is made of its own particular kind of atom. Compounds are made of atoms and molecules. Energy can be used in different ways to

Heat is a source of energy for extracting copper from its ores.

Equipment and Materials

See text page 72; also the Teacher's Manual for *Classroom Laboratory 6*.

Heat is a source of energy for extracting iron from its ore.

Equipment and Materials

See text page 81; also the Teacher's Manual for *Classroom Laboratory 6*.

Concepts of the behavior of matter had to be understood before metals could be used widely.

change matter. There are different forms of energy. From the listing, two central concepts should clearly emerge: *Matter can be changed from one form to another*, and *energy can be changed from one form to another*.

How did you learn these concepts? (By investigation.) How does understanding a concept do away with the trial and error method of learning? In your own investigations, you gain understandings and then apply them by designing other investigations; and you can design tools for investigating as well. Early man did not have the teachers, or the time, or the tools you have. No one is born with concepts; he must discover and acquire them by learning. Instead of trial and error, you can put ideas together and have an insight into the goal of each investigation you do. You build upon what others have learned and, so can help yourself to learn.

NOTE. Because of the length of this section, it may be desirable to divide it into two lessons. This may be a good place to bring the first lesson to a close.

Iron and steel. If possible, let pupils bend back-and-forth a strip of copper flashing such as builders use, or a piece of copper wire. Try to bend a piece of cast iron. What properties are noted? (The copper is soft and bends readily; the cast iron is hard and does not bend—actually it would break if subjected to heavy stress.) What are some advantages and disadvantages of each for buildings? for tools? for automobiles? Review the technology of steel by having pupils study the diagram of the blast furnace on text page 77. What two raw materials are essential to extract iron from its ore? When carbon combines with oxygen in the iron oxide, what gas is given off? (Carbon dioxide.) What product is obtained? (Iron.) Actually, this is cast iron in the form of “pigs,” which is brittle and fractures readily if hit a hard blow.

How is iron processed to make steel? Refer pupils to the diagram of the Bessemer converter (text page 78). What happens in the converter? Develop the idea that a mixture of iron and other elements is used to produce different kinds of steel. What properties does steel have that makes it so desirable? What are some of the ways in which steel is used?

The value of alloys. How would you like to have a penny of pure copper? Or a dime of pure silver? Or a carving knife of pure iron? The penny would bend, the silver would tarnish—and also bend—and the knife would rust. What properties would you like these metals to have? (Toughness, hardness, rust resistance, and perhaps lightness.) No matter how much they are refined, they still have the same properties. Suppose you dissolve sugar in water. The solution takes on the property of a liquid, but it also has the property of sweetness that water doesn't have. As the text indicates, early man—perhaps by accident—discovered that a mixture of copper and tin gave him bronze, a substance that was harder than either and did not corrode; that is, did not form oxides when exposed to the air.

Metals with new properties can be obtained if two or more elements, at least one of them a metal, are melted together and cooled.

Equipment and Materials

- ... copper wire or strip of copper flashing
- ... piece of cast iron

Alloys provide us with substances with advantageous properties.

As pupils finish reading the section, ask how bronze might have been discovered. What properties does it have that the two metals of which it is made do not have? Why was it so useful? (Presumably, it bridged the gap between the tipping of Stone Age tools with copper tips and the Iron Age, which began about two thousand years later.) What is bronze? (An alloy.) What is an alloy? (A combination of two or more elements, at least one of which is a metal.) It may be useful to inform the pupils that alloys are made by dissolving one substance (usually a solid) within another at a temperature at which the substances become liquid and allowing the mixture to cool. The particles of the elements in the mixture are so arranged that new properties result. Would a new alloy today be more likely to be discovered by trial and error or by the application of concepts; i.e., by goal-insight? Why?

Pupils might compile for display an enlarged chart of alloys, listed on page 79, indicating the elements of which they are composed and adding other special uses that result from the properties of the alloys. Stainless steel, for example, is used for razors, needles, and building trim, as well as for cutlery.

The role of plastics. What part do plastics play in your life? How many can you name that are in this room or are worn by your classmates? A listing might be quite long. Why were plastics developed only recently? Allow children to state their hypotheses in preparation for the work of the next section. (Actually, plastics are the result of the application of a number of chemical concepts about the ways in which atoms combine to form molecules. Substances consisting of these molecules have special properties—hardness, heat resistance, ability to be shaped, molded, cast, and so on.) A listing of plastics found in the home, used in industry, in science equipment for the classroom, in medicine, and in other areas—with their properties listed next to them—may be useful in leading into the next section of the textbook.

Extending the Concept

Conductivity of metals. Copper, of course, is a good conductor of electricity. It is also a good conductor of heat. Investigate heat conductivity. Hold a length of iron coat hanger and a similar length of copper wire of the same diameter in a pair of pliers, so that the ends are simultaneously in a flame. Place a forefinger on the wires next to the jaws of the pliers. Which feels hot first? Or, place a stainless steel and a silver spoon simultaneously into a pan of boiling water. Hold the handles at the ends. Which gets hotter first? What property in a substance would you look for in a handle if you wanted to use the heat-conducting properties of the metals and still not be burned? How is this idea used in kitchen tools? (Potholders, wooden and plastic handles.)

Malleability. Pupils may try to shape a length of copper wire into a paper clip. Let them test it in relation to an ordinary paper clip. Which does the better job? Why? (The paper clip is made of an alloy that holds



Chemical technology has provided many substances with useful properties.

Equipment and Materials

- ... coat hanger
- ... copper wire
- ... pliers
- ... aluminum foil
- ... stainless steel spoon
- ... silver spoon
- ... pan

Equipment and Materials

- ... copper wire
- ... aluminum foil

elasticity better than copper wire.) Or, place a 4-inch $\times$ 5-inch sheet of aluminum foil over a doorknob. With one hand, smooth the aluminum over the knob with a round-sided pencil, working it around the knob from the center out. When you have the rough form of the doorknob, remove the foil. Try to flatten the foil into its original shape. Metals can be shaped into different forms. Investigate the steps that need to be taken to transform a bar of aluminum into an airplane wing. Or imagine all the steps that must be taken to shape an iron washer from the iron ore from which it originally came. Try to indicate what concepts you would need to know and the kinds of tools you would have to invent, or at least use.

Alloys in space. The strength and heat resistance needed for space vehicles have intensified the search for new metal alloys. Among the most promising are the *cermets* (combinations of ceramics and metals), designed to protect the space capsule and its occupants from the enormous heat of re-entry into the earth's atmosphere. Seek assistance from your school librarian in learning more about alloys used in space exploration.

Work-hardened metal. When early man made big finds of pure copper, chunks were hacked out and hammered into tools and utensils. The hammering "work-hardened" the copper; that is, it became more brittle and less soft and pliable. To illustrate, hold a piece of copper wire in both hands. Quickly bend it nearly double and repeat until the wire gets **hot at the bending point**. Why does the wire become hot? (Relate to the behavior of molecules in motion, Section 2, text pages 60-64.) What happens if you continue bending the wire back-and-forth? (It breaks because it has become hard and brittle under heating.) Now lay one of the broken tips on any solid piece of metal. Give a sharp blow to the wire tip with the head of a hammer. Then hit the wire in the middle with the hammer head. This blow will dent the wire, but the tip will not be noticeably affected. Heating has changed the property of the wire at the "work-hardened" point. Pupils may wish to investigate further the meaning and techniques of tempering and case-hardening metals.

(Text pages 83-84)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. b 5. a 6. b 7. b 8. a 9. a

Using What You Know. 1. Technology had to invent and develop the tools. Also many other concepts dealing with the release of energy from matter had to be discovered. 2. a. They do not corrode. b. It is made of iron; the enamel keeps oxygen from combining with the iron to form rust. c. Copper was obtainable with relatively low heat energy; steel required the development of a furnace that could provide high temperatures; and aluminum required a knowledge of electricity.

Section 4: THE USES OF IDEAS AND TOOLS: NEW FIBERS

The pupils discover that synthetic fibers could be developed only after the chemical composition of natural fibers became understood.

Introducing the Concept

Hold up one or more samples of common alloys. A coin, a bronze medal, a brass fixture, or a stainless steel spoon will do. Next, display a piece of cloth made of natural fibers—such as silk or cotton—and another made of synthetic fibers—such as rayon, nylon, Orlon, or Dacron. Which material, the alloy or the synthetic cloth, was invented first? (The alloy.) Why do you think so? Encourage speculation, but at this point let the pupils' hunches remain the subject of further investigation. If they recognize that early man had to obtain metals (elements) from their ores (compounds) before he could work them, and that silk and cotton fibers (compounds) could not be imitated until modern man learned of what they are made, they are on the way towards understanding why the invention of synthetic fibers had to await formulation of concepts that deal with the chemical composition of organic matter. Encourage thought on this question as the pupils read.

What big idea (or concept) did man have to understand before he could invent new fibers? (The structure and chemical composition of matter—atoms and molecules.) What branch of science had to be developed? (Chemistry.)

Developing the Concept

The silk moth. Only the silk moth can produce silk fibers. Refer the pupils to the text to see how this is done. If any have raised silkworms, they may report their experiences to the class. Stress the strange and interesting partnership between the silkworm and the mulberry plant. The mulberry plant can live without the silkworm, but the silkworm could not thrive and make good silk without the mulberry plant. If moth cocoons are available at this time of year, pupils might compare one with the illustrations on text page 85 and attempt to unwind a short length of the fiber. It may then be examined under the microscope using the technique described on pages T-41-42.

Chemical concepts lead to new fibers. What sort of a change happened when you heated copper oxide? (A chemical change.) How do you know? (The copper oxide was separated into the elements copper and oxygen, two substances with properties different from those of copper oxide.)

You may wish to demonstrate what happens when cotton fibers are placed in a solution of household lye (sodium hydroxide), as mentioned on text page 87. Since lye is a strong caustic, it is best not to permit pupils to handle the lye. What kind of change do you think happened

(Text pages 84-91)

SUBCONCEPT

Knowledge of molecular structure enables man to invent new fibers with improved properties.

Processes emphasized

Observation
Categorizing
Hypothesizing
Investigation
Theorizing
Library research

Equipment and Materials

... samples of alloys
... silk or cotton cloth
... nylon or rayon cloth

Silk fibers are made by a living animal.

Equipment and Materials

... cotton fibers
... household lye (sodium hydroxide)
... milk
... white vinegar
... potato ricer or sieve

when the cotton fiber was dissolved in sodium hydroxide? (A chemical change.)

A simple analogy with the manufacture of artificial fibers can be made. Remove the heavy cream from the top of a pint bottle of milk, raw or unhomogenized. Heat the milk until lukewarm. Add white vinegar, a few drops at a time, until curds form. If you remove the curds (casein) and push them through a potato ricer or sieve, the appearance of threads will resemble the rayon process pictured and described in the text. The cotton sodium-hydroxide solution (viscose) hardens into fibers as it passes into a solution of sulfuric acid. Washed, the threads can be wound onto spools. Pupils should be referred to the diagrams in the text to see the changes in the molecular structure of artificial fibers.

Elements in natural and synthetic fibers. Cotton is a plant; silkworms eat plants. What elements would you expect to find in cotton fibers and silk fibers? As pupils recall how plants make food, they should infer that carbon, oxygen, and hydrogen would be found in plant cells and in the cells of the animals that feed on plants. When man learned this fact, what concept had he acquired? (Matter in both living and nonliving things is made of the same kinds of atoms and molecules.) Why was this concept necessary before man, as technologist, could invent artificial fibers that resembled fibers made by living things?

Rearranging atoms. Review alloys briefly. For example, bronze is an alloy of copper and tin. How do the properties differ? You may wish to explain at this time that the melting together of soft copper and tin causes a rearrangement of the atoms. Atoms are not of the same size. In the cooled alloy, copper and zinc atoms fit together so that they are difficult to push or pull out of position, and the bronze is therefore tougher and harder than either of the parent metals.

Does a rearrangement of atoms take place when man tries to improve on natural fibers? Pupils should study carefully the diagrams on text pages 88-89 before developing a response. Would you infer a difference in properties? (Yes.) What is your evidence? (The diagrams show that the atoms are attached in different places to form the molecules.) Pupils may be encouraged to compare the complexity of the molecules shown with the molecules of water and of carbon dioxide, for example, and to speculate as to why it took so long for scientists to understand the structure of the molecules in natural fibers and why artificial fibers were not invented until this century. What kind of atom that is found in all living things is also found in artificial fibers? (Carbon.) In the making of nylon, this atom is obtained from coal. How can we say that one of the raw materials for making nylon comes from a living thing? (Coal formed from green plants in past ages.) We might say that the invention of new fibers came about when man understood the chemistry of carbon compounds. As pupils read the text, they should note and compare differences in properties between natural and artificial fibers.

Fibers are made of common elements.

Atoms can be rearranged in molecules to form fibers with special properties.

Extending the Concept

Silkworm culture. Where conditions are favorable, interested pupils may investigate how silkworms are grown and make plans for their culture as a continuing project during the year. Or they may do reading research to compare the native American silkworm moths, *Cecropia* and *Polyphemus*, with oriental silkworms. For example, in a report, consider the "domestication" of the oriental silkworm with the "wildness" of the American species.

Fabrics in your life. Pupils may be encouraged to make classroom displays of different synthetic fabrics—nylon, rayon, Orlon, Dacron, Lanital, and others. Actual fibers or fabrics may be displayed with magazine and newspaper illustrations of their uses.

"Chance favors the mind prepared." This quotation from Pasteur can form the central idea for reports on scientific discoveries and inventions. Pupils might be referred to Charles Goodyear and vulcanization of rubber, William Perkin and synthetic dyes, Henry Brearley and stainless steel, Alexander Fleming and penicillin (which they will study in Unit Three), and to the subject of aluminum to compare the work of other scientists with Hall's successful process of extracting the pure metal.

What discoveries do you think still might be made? How could you train your mind to be prepared? One of the sure signs of a scientist is that his work never ends. One conclusion always opens up new questions, new problems—"Yes, but . . . what if. . . ?"

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. a 4. a 5. b

Section 5: THE MAIN CONCEPT: CHANGING THE ENVIRONMENT THROUGH SCIENCE AND TECHNOLOGY

As pupils review the history of man's increasing control over his environment, they more fully realize the relationships between the processes of the scientists and the products of the technologists—between concepts and their application.

CONCEPT SUMMARY

Gold and silver were possibly the first metals man knew about because they are found in the earth in their pure state. Of course, these metals do not occur everywhere and a find was rare then, even as it is today. What far richer but hidden sources of metals were under his feet? (Aluminum oxide in clay and iron oxide in rocks and soil.) Yet iron was not extracted from its ore until perhaps 5,000 years ago; nor aluminum in any useful quantity until the mid-nineteenth century.

TEACHING SUGGESTIONS

(Text pages 90-91)

(Text pages 91-97)

CONCEPTUAL SCHEME

Living things are interdependent with one another and with their environment.

UNIT CONCEPT

Living things are adapted by structure and function to their environment.

How can we show the growth of science and technology?

Processes emphasized

Concept seeking
Theorizing
Categorizing
Analysis of processes of scientists

Who is a scientist? Who is a technologist?

How do scientists work?

Before pupils read Section 5, suggest that they design a 10,000-year time line for science and technology. It may be as simple as a horizontal band at the top of the chalkboard or a vertical column divided into centuries, or as elaborate as a wire stretched across the classroom on which illustrations, or tag-board labels of two colors (to represent science and technology) may be hung at appropriate intervals.

At the beginning of the time line, pupils list the accomplishments of early man up to that date, using the information from their textbook or adding other items with which they may be familiar from their work in social studies (use of fire, stone tools, etc.). Where will you place the extraction of copper from its ore? (About one fifth the distance from the end point.) Next to this technological development, indicate the process by which man learned to obtain copper. (Trial and error.) Where will you place the beginning of scientific learning? (Probably near the "modern" end of the time line.) Where do you place the greatest advances in modern technology? (Still nearer the "modern" end.) What do the items on the time line show? (Until there was understanding of concepts, progress in technology was painfully slow; when the atomic and molecular structure of matter was understood, both science and technology became partners and moved rapidly.) The problems of the technologist led scientists to seek out concepts; the formulation of concepts led technologists to invent new products.

Pupils may not agree on an approximate date at which science began. Was the medieval alchemist a scientist? (No.) Did he have a goal? (Yes.) What did he lack? (Concepts that would have given him insight into designing investigations instead of using trial and error.) A good way to involve the entire class is to have a volunteer panel discuss the characteristics by which we recognize a scientist, considering such questions as these: How does a scientist prepare himself for his work? What processes of learning and investigation does he use? (The heading in the margin throughout this Teacher's Edition, "Processes emphasized," may serve as a clue to leading questions to guide discussion.) The panel must support by examples each characteristic they cite. Other pupils should be prepared to challenge both characteristics and supporting examples. Or the panel may similarly discuss the characteristics by which the technologist is recognized. Or both may be merged in spirited debate on the question: "Who has made the greatest contributions to modern life, the scientist or the technologist?"

Most pupils probably accept the statement that water boils at 212° F. Are you sure? How would you find out? (Easy! With a thermometer of course!) Suppose, though, you found that water boiled, with your thermometer, at 210° F. or 214° F. Would you jump to the conclusion that the thermometer was wrong? This simple question may be used to bring out discussion of certain scientific processes: questioning attitude, setting up a hypothesis, considering all the conditions, designing an investigation, repeating the investigation to check out accuracy of work as well as of

the tools used. (Accuracy of the thermometer, air pressure, and the purity of the water, for example, need to be considered.) How could the statement about the boiling point of water be changed to be more accurate? Pupils should recognize that the scientist questions every statement if he is unsatisfied that all the conditions have been tested. Why, however, does a scientist not have to test every question? He recognizes the honesty of scientists before him who have investigated a problem many times. Pupils should then recognize that technological advances rest on a solid foundation of tested hypotheses, evidence, and concepts.

In summary, you may wish to consider some of the following questions:

1. How did Hall's process of extracting aluminum show the testing of a concept? What was that concept?
2. How has the kinetic theory of heat been an aid to technology?
3. How did the knowledge of the structure of matter lead to the development of alloys? Of new fibers?
4. How has knowledge of concepts enabled man to change his environment? Why has he wanted to? What kinds of inventions do you think still should be made? Can you think of any problems that might have to be met?

FIXING THE MAIN CONCEPTS

Testing Yourself. 1. Pupil answers; essentially scientists seek explanations of objects and events while technologists apply the explanations to develop new products. Both are investigators. A problem of the technologist may suggest a question to investigate; a new or changed concept of the scientist may suggest an invention to the technologist. 2. The structure of the nucleus of the atom and the possibility of release of energy from it was not understood until well into the twentieth century. Technology had to invent devices to control the release of energy.

Quick Test. 1. b 2. a 3. b 4. b 5. a 6. a 7. b 8. a 9. a 10. a

(Text pages 95-97)



UNIT TWO

IDEAS AND TOOLS: FOR NEW PRODUCTS

To walk upon another world for the first time in human history is the greatest adventure ever planned. Yet by the turn of this decade man expects to set foot upon the moon. This adventure will generate a demand for new materials that are stronger, or tougher, or stiffer, or more resistant than existing ones.

Engineers who design structures constantly seek new materials that are stronger and stiffer than existing ones. The microphotograph on the opposite page shows silicon fibers imbedded in aluminum to increase strength but not weight.

Two hundred years ago, there was no penicillin, no nylon, no plastics, no steel bridges, no gasoline, and no aluminum. How did man get along without these things? How did they come about? What new materials will the future demand? Who will discover them, invent them, or design them?

Every significant advance in science is the result of the combined thought of many minds. Through the efforts of the scientists and engineers, each of us is able, through the application of research in astronomy, physics, chemistry, mathematics, medicine, and biology,* to develop into a happier, healthier, and more efficient citizen of the universe.

This unit begins a study of the way that man, as scientist and engineer, uses ideas and tools, imagination and skill, to produce new products to meet new demands.

1. Charles Hall and His Discovery

About 85 years ago, Charles Martin Hall, a student at Oberlin College, found the objective of his life's work. ■ In his chemistry class the teacher talked about the need for metals, especially aluminum. Aluminum is the most common metal in the earth's crust; but in spite of its abundance it was very expensive at the time that Charles Hall was in college. It was expensive because it was difficult to obtain *pure* aluminum from the earth. The price made its use impractical for buildings and for transportation. An inexpensive method of processing was needed. Scientists realized that quantities of aluminum could be used successfully in building and transportation if only it could be processed easily. All the common met-

als except aluminum and magnesium had been known and used for hundreds of years. Why, then, wondered Hall, was aluminum so difficult to produce? How and why was Hall able to develop a method for separating aluminum? Why had it not been done 200 years earlier?

After Charles Hall graduated from college, he began to investigate the problem of finding an easier and cheaper way to separate aluminum from its ore. His laboratory was the family woodshed.

One day he was able to give a dozen small pieces of aluminum to his former chemistry teacher. These pieces are sometimes known as "Hall's Jewels." A method similar to the one Hall used is still used today to obtain pure aluminum. It is used to produce very large amounts of the metal at a very low cost. ●



Aluminum Everywhere About You

Aluminum, the most abundant metal in the Earth's crust, is twice as abundant as iron. All igneous rocks contain aluminum, but aluminum usually remains insoluble in the form of clay. So, whenever you take a handful of clay from the ground, you may be picking up a compound containing aluminum. The aluminum is *chemically combined* with several other substances and has been in the earth for millions of years. It was there 2,000 years ago—1,000 years ago. Why then did man not use aluminum earlier? He did not know enough. He did not know as much chemistry and physics as is known today.

Two thousand years ago man did not know aluminum was in the earth. Even 150 years ago aluminum was not used. Man had not learned how to separate the aluminum compound from the crust of the earth, nor how to separate the pure element aluminum from its compound. Before this was possible, the concept of the way **elements** join to form a **compound** had to be understood. This concept is no more than about 150 years old.

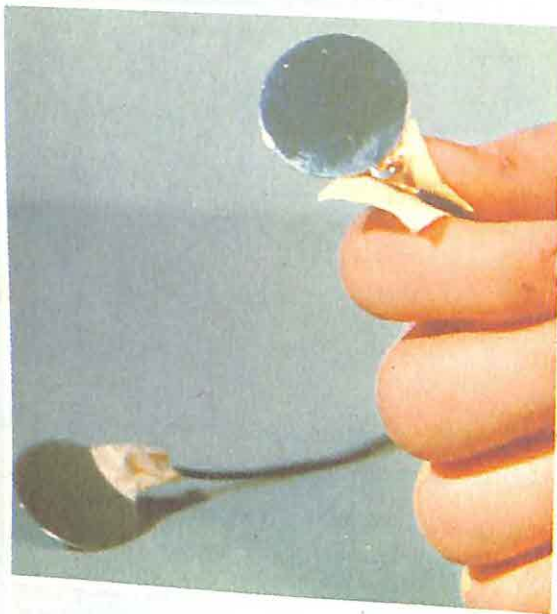
At that time, John Dalton, an English school teacher and scientist, had just begun to demonstrate that all matter was made of atoms, and he taught that these atoms combined to form compounds. Charles Martin Hall used this concept in his investigations of a way to separate aluminum from its compound.



It had been known before Hall began *his* work that some kinds of ore, especially the ore called *bauxite* (bôk'sit), are very rich in a compound called aluminum oxide. ▲ Oxygen is the other element in this compound. The aluminum and oxygen are combined chemically so that it is very hard to separate them. Hall's great discovery was a way of separating aluminum from its partner (oxygen) in aluminum oxide.

The investigation that you find on the next page will give you an idea of how pure aluminum is obtained, although the investigation is done with another metal, copper, which can be separated easily from its most common compound, copper sulfate. In school laboratories, it is not easy to separate aluminum from its compound (the oxide), but the idea is much the same if we try to get the pure metal, copper, from copper sulfate. Try the next investigation.

AN INVESTIGATION into What Happens



DANGER: The compound copper sulfate is poisonous.
DO NOT GET ANY IN YOUR MOUTH.
Wash your hands after the investigation.



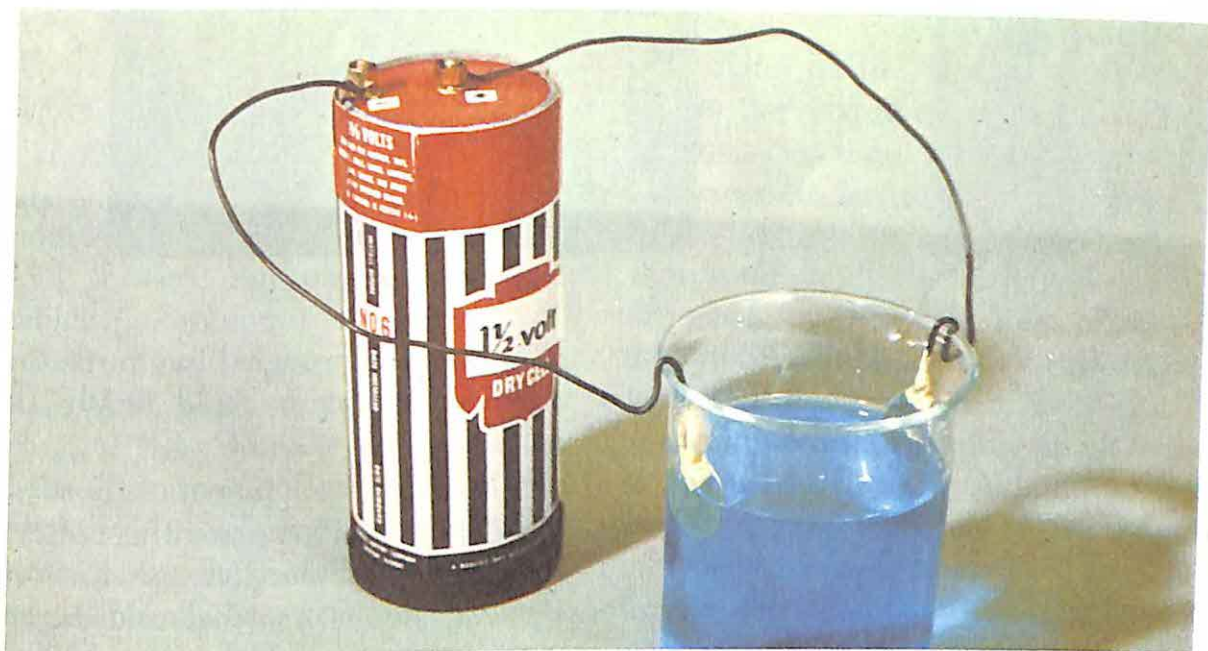
Needed: about 3 teaspoonfuls of copper sulfate; two glasses; water; two pieces of insulated wire about 1 foot long; a dry cell; and 1 tablespoon of washing soda

You will also need two small pieces of silver: perhaps two silver coins or old unwanted pieces of jewelry, such as charms from a charm bracelet. Any silver or silver-plated objects will do. *Check with the owner to make sure that the items are no longer wanted.*

Remove the covering from one end of each of the copper wires. Wash the pieces of silver in some hot water and washing soda, to clean their surfaces. It is sometimes necessary to wash the pieces of silver several times to remove any oil or lacquer. When the silver is clean, it will have a dull appearance rather than a bright, shiny one. Tape the end of each piece of wire to a piece of silver, as shown. ■ Remove the covering from about $\frac{1}{2}$ -inch of the other end of each wire. Connect these ends to the dry cell, as shown. Use *only one* dry cell. ●

Pour hot water into the glass until it is three-quarters full. Add 1 level teaspoonful of copper sulfate to the hot water, and stir until the compound is dissolved. Then, add 2 more level teaspoonfuls of copper sulfate and stir until they dissolve.

When an Electric Current Is Passed Through Copper Sulfate



Now put the pieces of silver into the solution, but do not let them touch each other. ▲ Leave them until you see that one of the pieces of silver has turned a copper color. ♦

What has happened? First, an electric current goes from the dry cell through the compound copper sulfate.

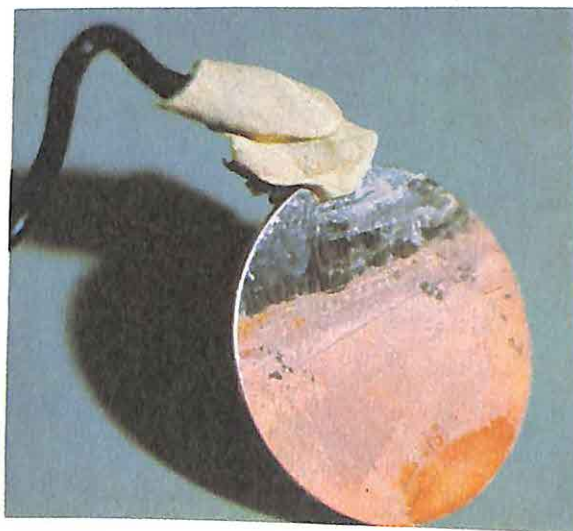
The coin becomes coated, or plated, with copper. Where could the copper have come from?

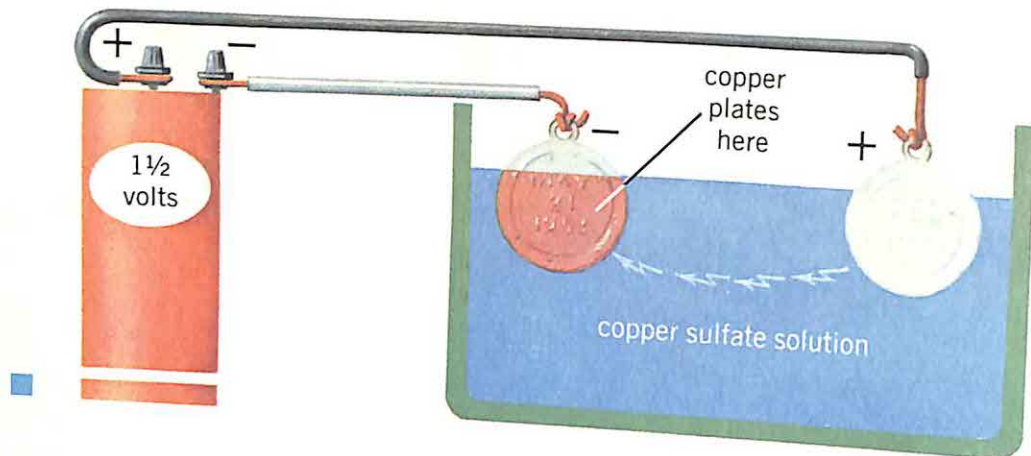
If you leave the coin in the **solution** long enough, the blue color seems to disappear. The copper sulfate is gone. What is your explanation?

Additional Investigation: To which terminal on the dry cell is the coin that receives the coating of copper con-

nected? What happens if you change the terminal to which each coin is connected?

How would you explain what happens? If you cannot explain it, where would you go to find out?





From Our Copper to Hall's Aluminum

A good explanation of the effect that an electric current has on copper sulfate is this: the copper leaves the solution to plate the silver coin or charm. ■ Electric energy causes the pure copper to separate from its compound, copper sulfate.

Does the same explanation hold true for separating aluminum from aluminum oxide in the ore bauxite? If so, what did Charles Hall need? He needed an electric current. Furthermore, he needed the aluminum oxide in a form that would conduct electricity easily. The aluminum oxide had to be dissolved in a melted substance called *cryolite* (krī'ə.līt); it will not dissolve in water, as copper sulfate does. When Hall passed an electric current through the solution of aluminum oxide and melted cryolite, the pure aluminum came out of the bauxite in the solution.

What an important discovery! Of course, it had been known that an electric current could break up certain substances, but Hall made this idea work for him by inventing a way

of using it. Through his efforts the element aluminum could finally be made useful.

It was the development of the electric generator to replace the battery as a source of electricity that made possible the economical and large-scale production of aluminum. Continued research and development has put aluminum in a very important position. It is second only to iron among metals.

Look at the picture on the opposite page. The aluminum "plates" out and settles on the bottom of the tub as a liquid. ● Then the liquid aluminum is run off at the bottom and cooled to form pure solid aluminum ingots (ing'gəts).

Aluminum may be cast into ingots for rolling into bars, rods, sheets, or foil. It can be drawn into wire, and it can be forged. It can be drawn down to tubes of any desired diameter and wall thickness. It is a good reflector of light and is used in the lighting industry. It is a good conductor of electricity and is used in the electrical industry. It is used to make col-

lapsible toothpaste tubes. Today, ceramic engineers use it to make a variety of things harder and stronger, nose cones on rockets, for instance. There is no foreseeable end to the list of uses for aluminum.

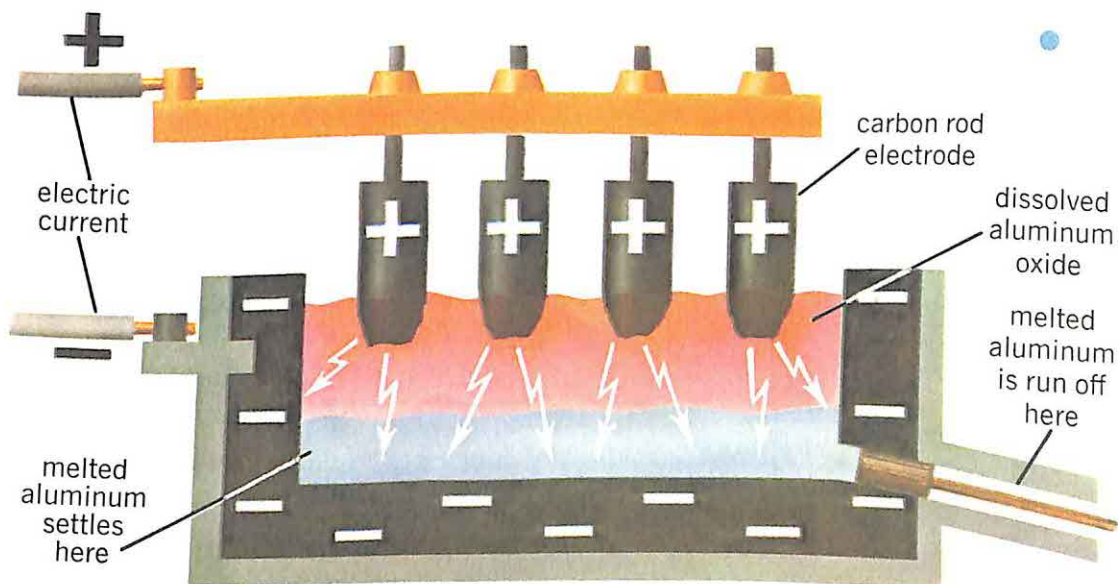
Look about you. You will find many objects made of aluminum: pots, pans, ladders, aluminum foil, and screens. Because it is light in weight, aluminum is used in airplane construction; because of its strength, it is often used to replace steel and copper. Like iron, it does combine with oxygen; it forms aluminum oxide. A thin coating of aluminum oxide, however, protects the pure aluminum beneath it, whereas the coating of rust on a piece of steel does not protect the metal. Sooner or later the steel will rust through.

Under certain conditions, the oxide coating on aluminum will absorb various dye stuffs. Colored aluminum is used extensively for many purposes.

Ideas and Tools: Relatives in Discovery

A study of the way Hall produced aluminum is important for many reasons. One of the reasons is that it shows the advantage of man's brain. It shows how man can use a discovery to change his environment and, thereby, to improve his way of life. Aluminum compounds always have been in the earth, but bears, or lions, or monkeys are not able to take advantage of them. Man *can* and *does*. He invents not only *new tools* but also *new ideas*, or concepts. It is important that you consider both of these aspects of man's activity as a scientist.

Man is interested in what is going on around him in the universe. He observes, analyzes, and reflects upon what he has observed. He asks endless questions, usually of himself. Some of the best ideas are nothing but questions. In fact, the business of science is one of asking questions. The





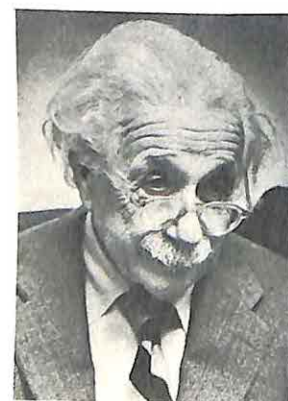
Isaac Newton
(1642–1727)
concepts of motion,
gravitation,
and light



John Dalton
(1766–1844)
concept of matter
as particles



Louis Pasteur
(1822–1895)
germ theory
of disease



Albert Einstein
(1879–1955)
concept of
relativity

kind of science one gets depends on the kind of questions one asks, and some of the answers have become the major *concepts* of science.

As an example, scientists have developed, after many hundreds of years, an explanation of the structure of the material universe—the world of matter. In developing this explanation, they observed and investigated the odd assortment of the billions of things we see around us—rocks, rain, and robins; pencils, paper, and pebbles; sand, salt, and seaweed; trees, toads, and tin; water, wax, and worms; the moon, man, and money.

It is one thing to look at each of these things separately. They seem to have no relationships between them, to be totally different, helter-skelter, scrambled, without order.

It is another thing to discover that all these things *are related* in that they are all made from tiny particles, **atoms** and **molecules**. An understanding of this concept that *all matter is composed of combinations of less than 100 different kinds of tiny particles* brings order out of disorder. The billions of things around us may not be helter-skelter after all; they are indeed related in that they are all composed of atoms and molecules.

Developing concepts, then, about the universe, is one aspect of man's activity as a scientist.

Another aspect of man's activity as a scientist is his interest in using these concepts to invent things that work—tools, machines, or new materials. As

we have seen in the case of Charles Martin Hall, this kind of scientist or engineer takes the concepts that have already been developed, and applies them for some special purpose. Charles Hall did this when he separated aluminum from its ore.

Hall used concepts that had been developed by other scientists. For instance, he combined his knowledge of the concept that *matter is made up of particles* with the concept that *energy can be changed from one form to another*. On the basis of his understanding of these two concepts, he split the compound aluminum oxide by means of electric energy. He separated the element from the compound.

You will come across the two aspects of man's activities as a scientist again and again. The one aspect in which he *seeks* to explain what he observes in the universe is usually called pure science. The other aspect, in which he *applies* the concepts of science to invent tools, machines, or materials is called applied science or **technology** (tek.nol'ə.jē).

To use another example, the pure scientist is mainly interested in explaining light; the applied scientist, or engineer, is primarily interested in inventing a light bulb. When the applied scientist works on light bulbs, however, he may actually find out a great deal more about light. In the same way, when the pure scientist investigates light, he may discover a way to make a better light bulb. Ideas and inventions go together.

Thomas Edison
(1847–1931)
technology of
electricity



Guglielmo Marconi
(1874–1937)
wireless
communications



Jonas Salk
(1914–)
medical research
and development



Wernher von Braun
(1912–)
rocket research
and development



It is very hard to find a person who is a pure scientist only or an applied scientist only. Most scientists are a combination of both. Ideas, or concepts, and tools go hand in hand; but

perhaps it is more correct to say that the scientist is interested in concepts, while the engineer is more interested in techniques involved in tools, machines, or materials.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. To get aluminum we must separate it from
 - a. cryolite
 - b. bauxite
2. An electric current can release copper from
 - a. copper sulfate
 - b. aluminum sulfate
3. In order to electroplate a substance, the substance must
 - a. conduct electricity
 - b. not conduct electricity
4. Hall's work in separating aluminum from its ore is an example of
 - a. pure science
 - b. applied science

B. Write a paragraph or two on this topic: Science and Technology.

USING WHAT YOU KNOW

Engineers are primarily concerned with advances in technology. (This is not to say that engineers are not interested in pure science.) On the basis of what you now know about technology, who would you say is primarily responsible for work on rockets, scientists interested in pure science or scientists interested in technology?

ON YOUR OWN

Which of the following men were more interested in technology than in pure science? The library will help.

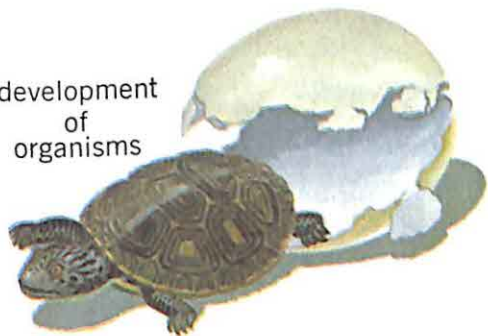
Charles Hall
Wernher von Braun

Albert Einstein
Louis Pasteur



northern lights

development
of
organisms



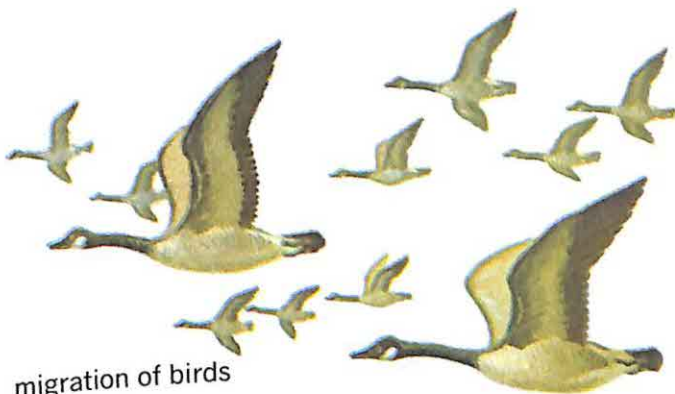
pull of gravity

2. Uses of a Concept

In this part of your book you have been reading about the uses of discovery. You have been focusing attention on how man *uses* the concepts of science to improve his way of living. There is much more to a concept, however, than its use in technology. A concept in science that developed from observation of certain objects and events can often be expanded to explain other objects and events.

Events that the scientist seeks to explain are called phenomena (fī-nom'ə-nə). ■ Examples of such events are weather, the fall of meteors, the revolution of the planets, the pull of gravity, the migration of birds, or the transfer of heat.

Would you be surprised to find that the concept *matter is made of particles* helps us to understand one of the most important phenomena of our environment—heat? What is heat? Several investigations may help you to find out. Try those suggested on the following pages.



migration of birds

■ SOME SCIENTIFIC PHENOMENA

AN INVESTIGATION into the Motion of Molecules



Needed: two Pyrex beakers; hot and cold water; ink; a medicine dropper; a watch

Fill the two Pyrex beakers almost to the top. One should be filled with very hot water and the other with very cold water. Allow the beakers to stand until the water is quite still.

Put exactly four drops of ink into each with a medicine dropper. ■ Place your watch on a nearby table and note the exact time when the ink was added.

Watch closely! Notice how the ink swirls around and begins to mix with the water. ● Notice how the swirls continue to move. Why are they moving even though the water seems to be quite still?

The molecules of ink are mixing with the molecules of water. Are the molecules of ink moving?

Which seems to be moving faster, the swirls of ink in the *hot* or in the *cold* water? Which molecules of water are moving faster, those in the hot water or those in the cold water? ▲

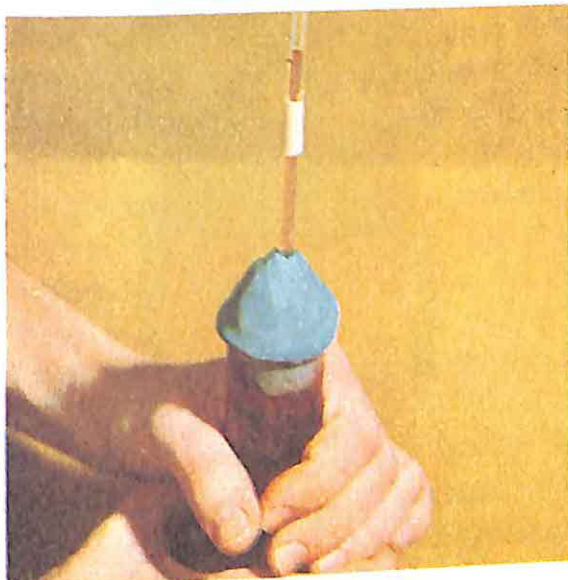
How long does it take the ink to become completely mixed with the hot water?

How long does it take to mix with the cold water? What is your explanation for the difference in time?

Now try the investigation on the opposite page. Analyze the results of each.



AN INVESTIGATION into the Nature of Heat



Needed: a flask; a small vacuum bottle; modeling clay; a long tube; some water; ink

Set up the flask exactly as shown in the picture. It is important that the flask be filled with water.

Color the water with several drops of ink. Place the modeling clay and tube in the flask. Press down until the water rises part way in the tube.

a. Hold your hands around the flask for 5 minutes. What happens? ■

b. Repeat the investigation, but use a vacuum bottle (that has been removed from its case) in place of the flask. ● Compare the results from both. Get the average from several trials.

A number of students who did this investigation got the results below.

How do you explain their results? How do they compare with yours?

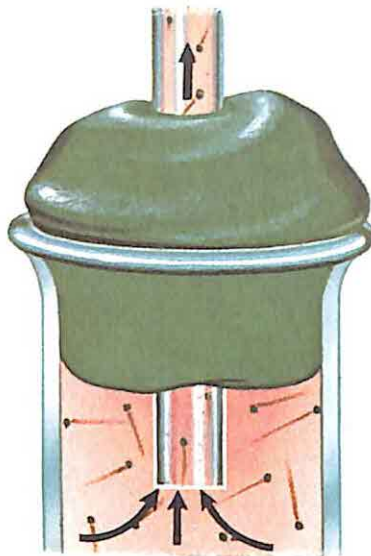
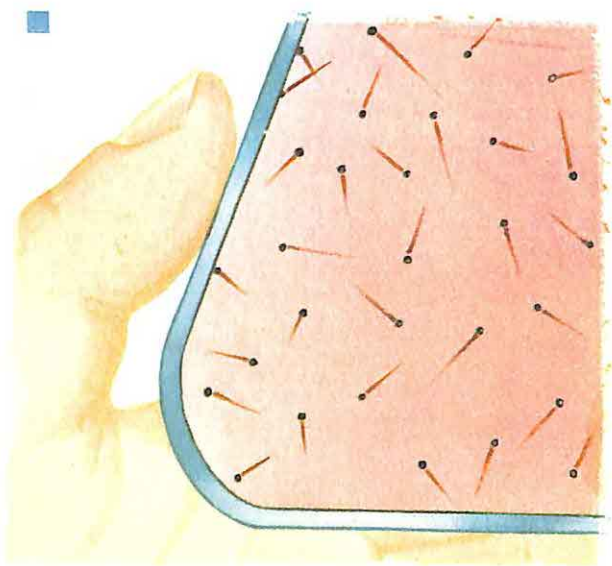
	<u>Rise of Column of Water</u> (in tube with flask)	<u>Rise of Column of Water</u> (in tube with vacuum bottle)
1. Average of results of investigations by 11 students in a class in New York	$1\frac{1}{2}$ in.	no rise
2. 22 students in a class in Ohio	$1\frac{7}{16}$ in.	$\frac{1}{16}$ in.

The Energy of Moving Molecules

The human body is warm. Some of the *chemical energy* derived from the food we eat is changed to *heat energy*. The rest of this chemical energy is used for movement of the body, for growth, and for other body functions. Some of the heat energy can be transferred from the body to the flask.

How do you know that heat energy is transferred? The evidence is found in the investigation on page 59: the column of liquid rises in the tube from the flask in the same way that a liquid rises in a *thermometer*.

Why does the column of liquid rise? Let us try to apply the concept that *all matter is composed of particles* (in this case the particles are water molecules) to explain why the liquid rises. Reason this way: The liquid is composed of molecules of water. Heat energy is transferred from your body to the water by holding your hands around the flask. ■



The water expands and occupies more space as it moves up the tube. ● Why? You did not add more molecules of water. Therefore the *same* number of molecules must be occupying *more* space. How can the same number of molecules occupy more space? The motion of molecules is the answer.

The moving ink swirls in the first investigation (page 58) demonstrated that even though the water appeared to be quite still, the particles of water must have been moving in order to mix with the particles of ink. On the basis of this observation we now can add the concept that *molecules of matter are in constant motion* to the concept that matter is composed of molecules.

With this expanded concept we can now explain more fully how the same number of molecules can occupy more space. When the heat from your hands was transferred to the molecules of water in the flask, the

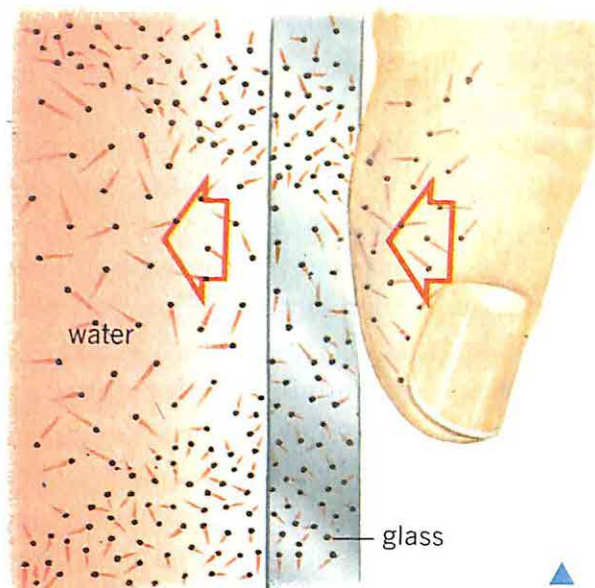
molecules began to move faster and faster. (Recall the faster-moving ink swirls in the beaker of hot water on page 58.) As the molecules in the flask moved faster, they pushed farther apart. They bounced faster and harder against the sides of the flask; but the sides of the flask are rigid and do not move, at least not so you can notice. The only way then for the molecules to move farther apart is to move farther up the tube. The **volume** increases while the number of molecules remains the same.

The warmer the liquid becomes, the higher the liquid will rise in the tube. As the liquid cools, the column will fall. You can determine this by putting the flask in a refrigerator for an hour.

If you recall the beakers of hot and cold water on page 58, it was the beaker of hot water that showed the greatest activity (the molecules were moving faster). It is from such observations that scientists have come to explain heat as *the motion of molecules*.

Molecules occupy space. The faster they move, the more space they occupy. This is the reason that a thermometer works. As the temperature rises, the molecules move faster, so that the liquid expands and rises in the tube. What about gases and solids? Do they also expand when the temperature rises?

Anyone who observes what goes on around him realizes that most materials expand as their temperature

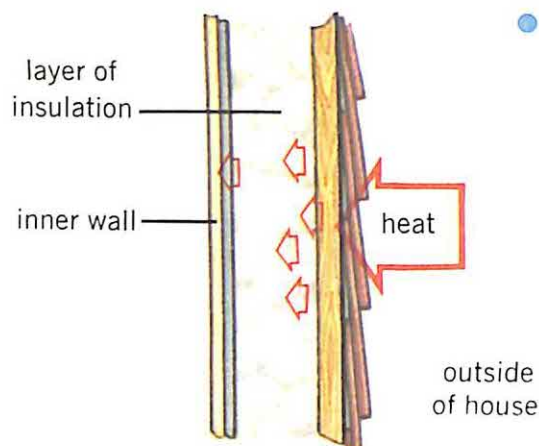


rises. The expansion of gases is far greater than that of liquids, but gases and liquids expand more than solids.

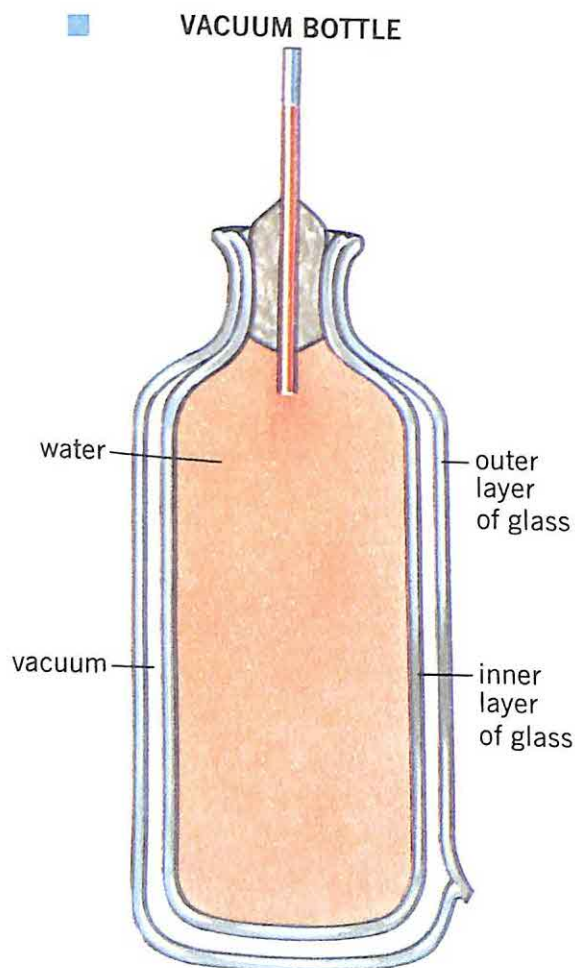
Designers and builders of many common objects must be aware of expansion and provide for changes in size. Bridges must have joints which allow for the maximum expansion on the hottest day. Cracks are left in sidewalks to keep them from bending under pressure. Do you know of other situations in which expansion could be a problem? Do you know any useful effects of expansion? Remember that expansion occurs when the temperature rises.

The water in the vacuum bottle did not get warmer when you held your hands around it. Why not? Reason this way: Heat is transferred from one place to another by moving molecules. Molecules in the wall of a glass flask will transfer the heat from your hand to the water inside, as shown. ▲

However, a transfer of heat cannot take place easily through the walls of a vacuum bottle. Look at the diagram below. ■ Notice that the vacuum bottle has two layers of glass. Between the layers of the vacuum bottle most of the air has been removed and very few molecules remain. For that reason, heat is not transferred. There is a shortage of moving molecules in a vacuum. The vacuum serves as an **insulator** (in'sə-lā'tər). Insulators slow down the transfer of heat from one place to another. They can be used to keep heat out or to keep heat in. What makes a good insulator?



Certain materials can slow down the motion of molecules. They make good insulators also. Insulation, in the walls of a house, traps tiny pockets of air that can help keep heat in (in the winter) or help keep heat out (in the summer). The illustration shows how insulation can be used. ●



The Nature of Heat

Heat is the energy of moving molecules. The faster they move, the greater the heat. The faster they move, the more space they occupy, if they are not enclosed. Would you say that the molecules of a gas move faster or slower than the molecules of a liquid?

The molecules in ice, water, and water vapor are the same except for their motion. When the molecules in ice or water move fast enough, they can escape and move as individual molecules of water vapor, a gas. Changing from ice to water and then to water vapor is only a matter of transferring heat from one place to another; and heat is the energy of moving molecules.

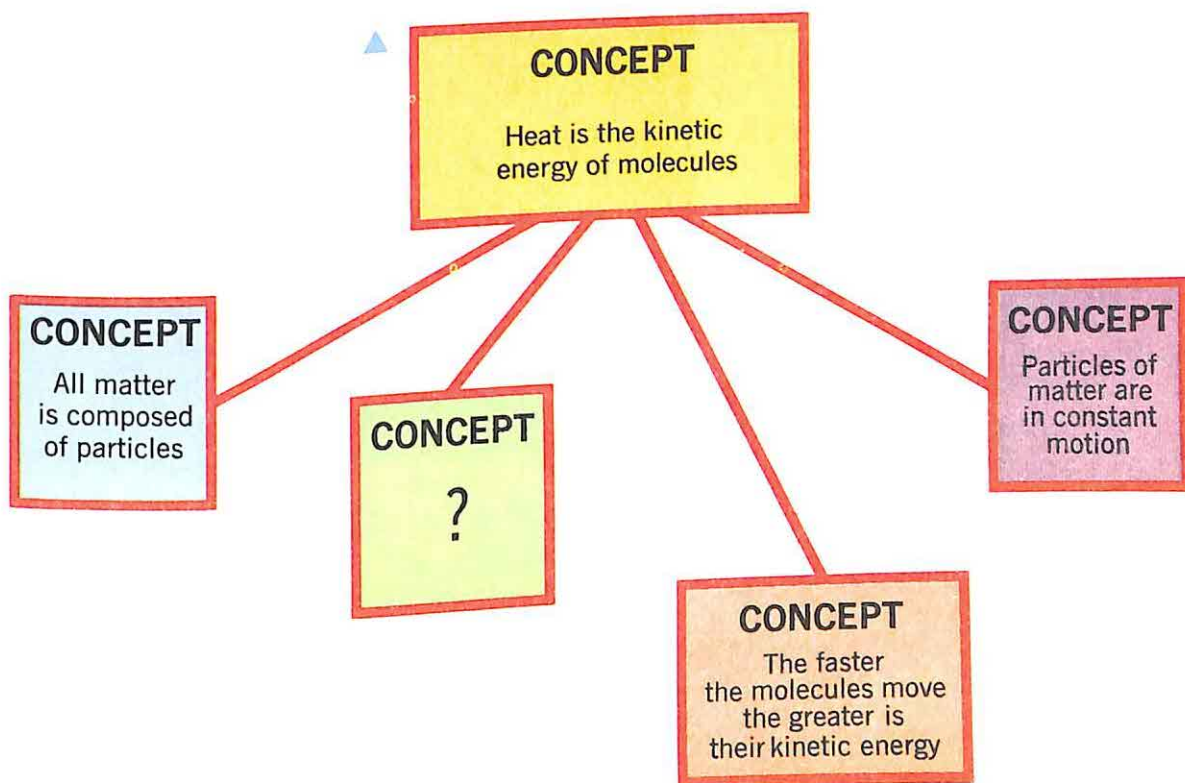
Moving molecules have **kinetic energy** (ki-net'ik en'ər-jē). Kinetic energy is energy of motion. Fast-moving molecules have more kinetic energy than slow-moving molecules. If heat is the energy of moving molecules, then heat energy is one kind of kinetic energy. This is a very important concept about the nature of heat.

When molecules collide, that is, when molecules bump into one another, some of the kinetic energy of the faster-moving molecules can be transferred to the slower-moving molecules. The amount of energy transferred depends on the mass of the molecules. Why? Kinetic energy depends on both the mass of an object and its velocity. This is an important

point to remember about the nature of heat. Now, to the concept that *all matter is made of particles* can be added the concept that *heat is the kinetic energy of molecules* and that energy can be transferred by the collision of particles.

This explanation for the nature of heat is called the **Kinetic Theory of Heat**.▲ The kinetic theory will be very useful as you study the behavior of molecules. In any event, the kinetic theory enlarges our understanding of the world about us.

The world of matter is a world of particles. Furthermore, these particles of matter have kinetic energy. They are in constant motion. An understanding of the concept of parti-



cles in motion results in some very important uses. For instance, by using the concept you can explain the phenomena illustrated below. ■

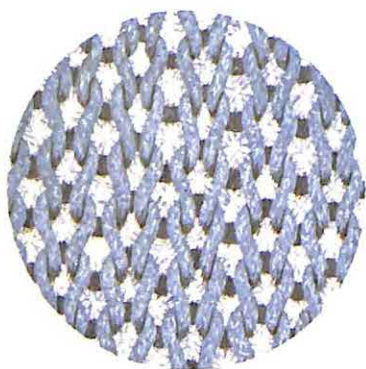
The scientist *develops* a concept through investigation of the objects and events around him. The engineer *uses* a concept or concepts in a different way from the scientist. The engineer uses concepts to invent many useful tools, materials, and objects. For example, engineers have applied the concept of molecules in motion to the invention of such things as rockets, engines, insulation, valves, and other devices. A few of these devices are shown on the opposite page. ● With these devices he changes the environment and activities of man.

Do you now see how ideas and tools, or science and technology, go hand in hand?

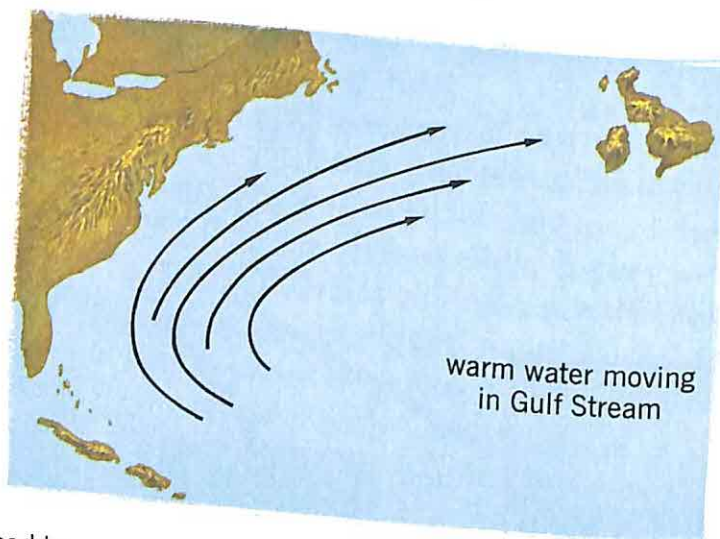
Sometimes, however, the invention comes before the explanation. As the scientist tries to explain the invention, he develops the concept. Once the concept is understood, inventions increase at a much faster rate.

For anyone who is interested in the world around him and is curious about the amazing progress of man's mind, few subjects are more interesting than a history of inventions. You would find how they have changed the patterns of human life down through the ages.

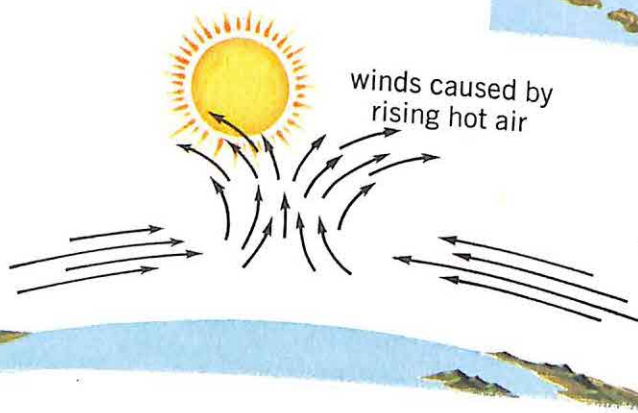
We become aware of this in the next section as we take an imaginary visit to an ancient dump.



air trapped by wool fibers

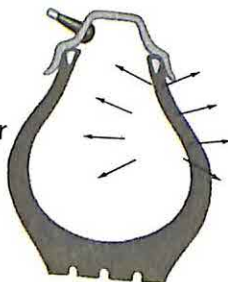


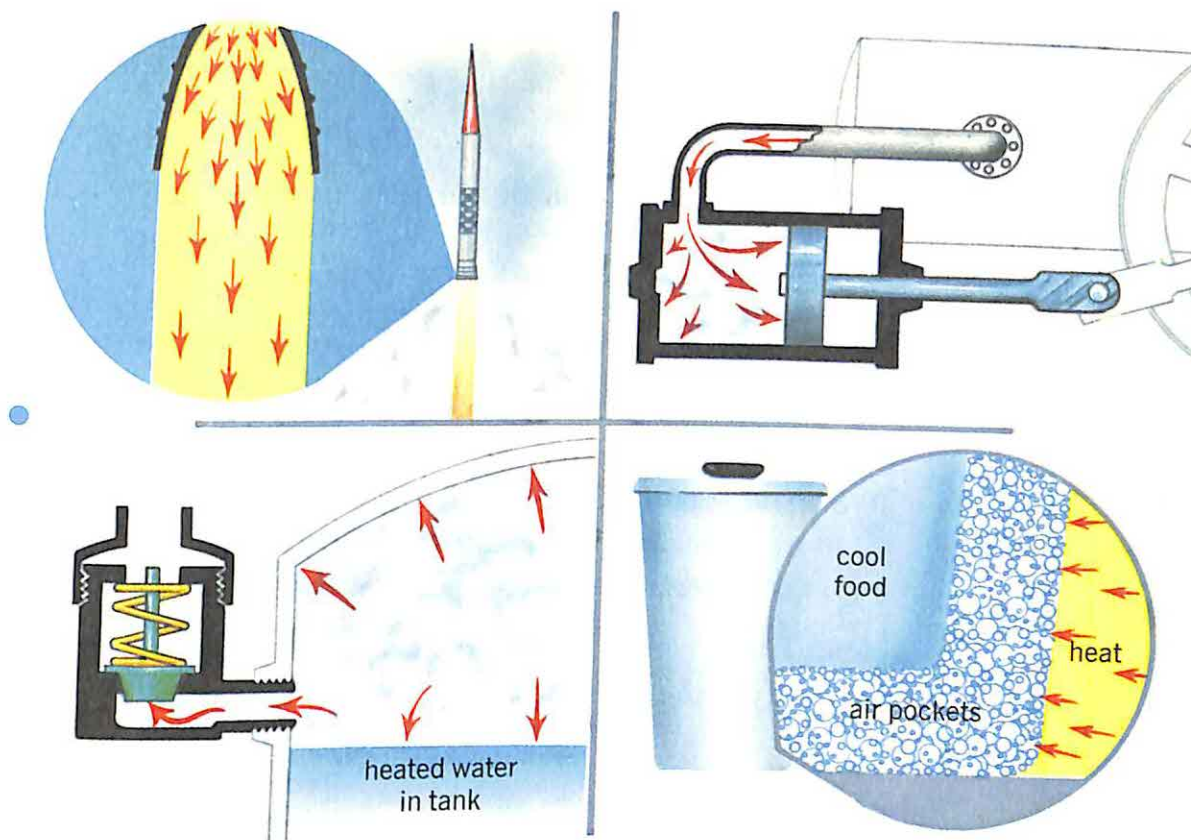
warm water moving in Gulf Stream



winds caused by rising hot air

tire gets harder on a hot day





**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. If there were no light or heat from the sun
 - a. all life would cease
 - b. the air would remain a liquid
2. *Matter is made up of particles* is a statement of a
 - a. scientific event
 - b. scientific concept
3. In the body the chemical energy in the food we eat is
 - a. completely changed to heat energy
 - b. partly changed to heat energy
4. The phenomenon of heat can best be explained this way:
 - a. particles of matter are in motion
 - b. there is a substance known as heat energy

5. When the motion of particles in a substance is very great, kinetic energy is
 - a. high
 - b. low
6. When the motion of particles in a substance is low, kinetic energy is
 - a. high
 - b. low
7. When the kinetic energy of a substance is increased, its heat is
 - a. higher
 - b. lower
8. The Kinetic Theory of Heat is best used to invent
 - a. better insulating materials
 - b. ways of getting animals to produce more food
9. The development of concepts is primarily (although not always) the work of the
 - a. scientist
 - b. engineer or technologist
10. Inventing new materials and machines is primarily (although not always) the work of the
 - a. scientist
 - b. engineer or technologist

USING WHAT
YOU KNOW

B. Write a paragraph or two (with examples) on this topic:
The Importance of a Concept.

1. Science and technology go hand in hand. Explain how this might be so in the invention of a new kind of tire, one that resists blow-outs more than any present tire.
2. Suppose scientists could reduce the temperature of a substance to absolute zero. The temperature of absolute zero means that *no molecules would be in motion*. Describe at least one of the conditions which you would suppose to be true of that substance.
3. Cryogenics is a branch of science which deals with very low temperatures. It is a branch in which a great deal of research is being done. Watch for current news items.

ON YOUR OWN

You know that accurate measurement is important to the development of any concept in science.

Investigate on your own the way in which the temperature of a substance is measured. The two most common scales used to measure temperature are called the Fahrenheit scale (which is probably familiar to you) and the Celsius scale. ■

What is the freezing temperature of water on the Fahrenheit scale? on the Celsius scale? What is the boiling temperature on each? How many degrees difference is there between boiling and freezing on the two scales?

Can you convert a temperature reading from the Fahrenheit to the Celsius? How would you convert 20° Celsius to the Fahrenheit scale?

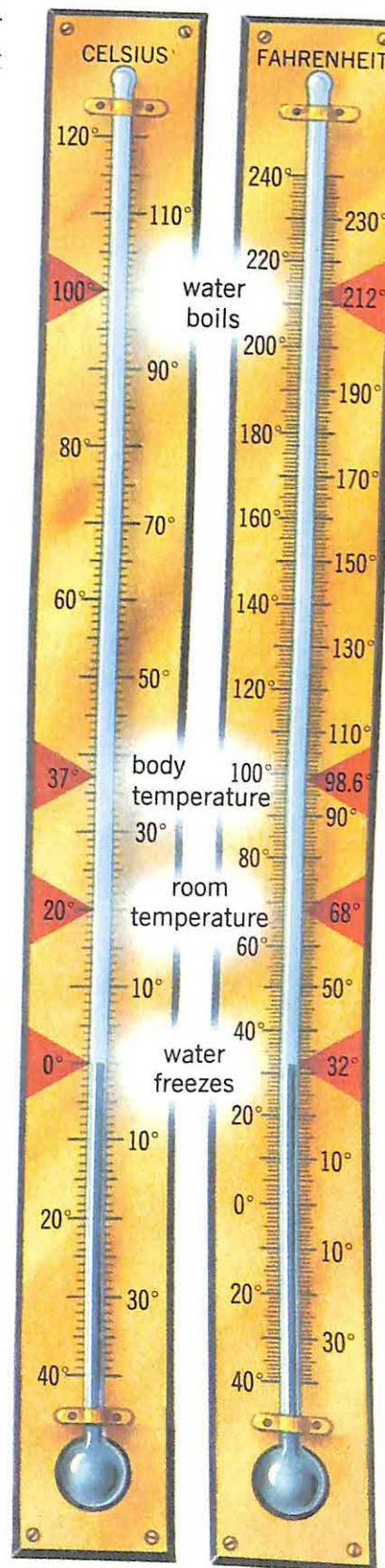
Just as we sometimes change feet into meters, there are times when it becomes necessary to change a temperature reading from one scale to the other.

Lacking a scale which gives both readings at once, the following formulas are useful in converting back and forth from Celsius to Fahrenheit:

a. $C = \frac{5}{9} (F - 32)$

b. $F = (\frac{9}{5} \times C) + 32$

Explain in your own words the concepts which underlie the development of the thermometer as a tool for the scientist. How many ways do you know that thermometers are useful?





3. The Uses of Ideas and Tools: New Metals

Beavers, ants, bees, and swallows are all constructive animals, but their cells, nests, and burrows are the same today as they were years and years ago. They do not change their way of doing things. Man alone among living things can invent and change the natural order. He progresses by means of his inventions.

Sometimes man invents or discovers a way of doing things before he can state the concept which explains it. We go back to ancient man to find an example.

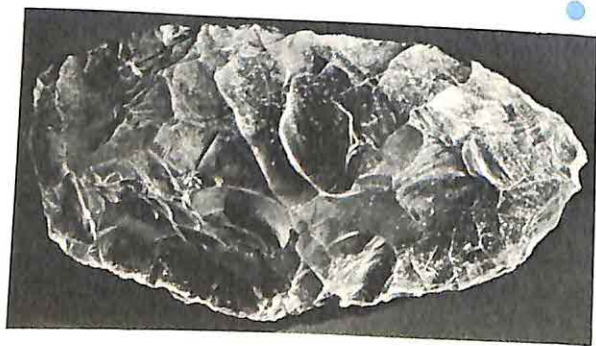
In a way, we are lucky that ancient man had no garbage trucks. When he

finished eating an animal, he threw the bones on the ground or on the floor of his cave, alongside his broken tools. ■ These ancient dumps tell us a great deal about the way ancient man lived.

For instance, as different tribes moved into the caves, they used different tools. Suppose tribe A lived in the caves first and used a kind of axe known as a hand axe. ● Many years later tribe B moved into the caves. Suppose they used axes with a handle or haft and discarded them in the same dump as tribe A. ▲

Scientists of today, digging in the dump, would find the remains of both kinds of axes. The broken tools of the tribe which came first would be found in the dump *below* those of the later tribe. In this way, scientists can tell which tribe came first.

By studying these ancient dumps, called kitchen middens, scientists have been able to piece together a story of how early man used the things he found around him. This story is told in the tools he used.



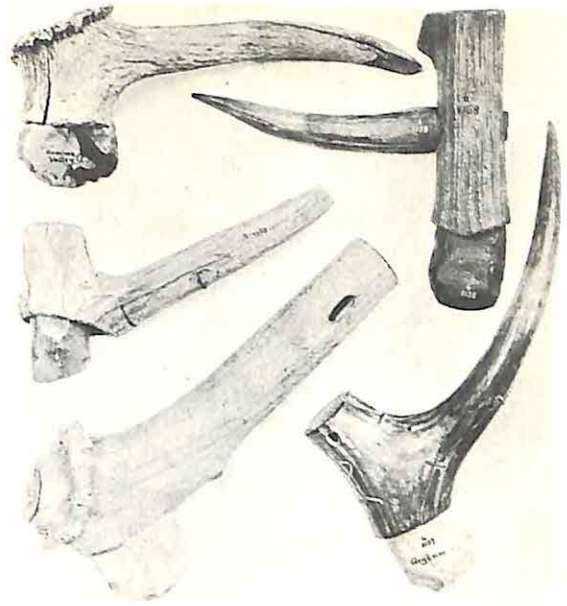
Study the photograph of some tools of ancient man. ♦ Can you guess which were the tools of the earliest tribes? Check your guesses with the answers given at the bottom of page 71. Which tools were made by the later tribes?

How did early man happen to invent and use tools? This is an important question. No living thing, other than man, has ever been able to do this or is able to do it now. Furthermore, early man learned from the men who came before him, even as you do now.

We have evidence that about a million or so years ago, there lived in Africa a creature that walked upright. Skeletons of these creatures have been found. Near their skeletons have also been found the skeletons of baboons that died because of blows from stones which broke their skulls. Someone had killed them with stones that had been sharpened. Man had found a stone and invented a weapon. He took a stone from nature, changed it, and made it a part of his scheme of things.

An Advance

For hundreds of centuries man knew nothing about metals, although he did know that with fire metals could be extracted from ores. Any attempt to explain how man discovered metals can only be a calculated guess. In all likelihood, the discovery of metals came about by sheer accident.



From your study of aluminum remember that man is not always aware of *all* the materials around him. He had to learn from experience *what* the materials are, and *how* they can be used. For example, in the time of early man, coal and oil were present in the crust of the earth, but he did not use them. Copper and gold were there also, undiscovered and unused.





The soil was there, but man had not yet learned to cultivate the soil to grow his crops.

It took thousands of years for man to become a farmer, a *food-producer*. Before he became a food-producer, man had been a *food-gatherer*. That is, he gathered the fruits, berries, and nuts that he found around him. He hunted the animals. In this stage of food-gathering, he did not plant



seeds, nor did he raise his own animals for meat. He was not yet a food-producer.

Before man became a farmer, he had to invent and learn to use the tools he needed to work the earth. It took a long time before he learned to make a plow. The first plow may have been just a stick like the kind still used in some places on the earth. ■

In order for man to become a food-producer—to produce food by planting and harvesting or to produce animals and animal foods (milk, meat, and eggs) by domestication and care, man had to invent tools. He had to invent a technology which would help him produce food. Wooden and stone tools, although useful, were not good enough. They wore out easily; they broke; they were not hard enough.

Soon man was to discover metals. The first metal he discovered, more than 8,000 years ago, was copper. This was a natural discovery, because unlike aluminum, the element copper could be found in many places in its pure form. The copper did not have to be separated from any ore. ● Ancient man found deposits of pure copper in many places. Much of it was on top of the ground. He soon learned to shape spearheads and tools out of copper. For many centuries man used weapons and tools made from “native” copper, as it is called. He had no idea that he could get much more copper from ores. He had not yet discovered that metals could be separated from many rocks, or ores.



The discovery of metals happened long before man had any idea what atoms and molecules are. Perhaps the discovery that metals could be separated from ores happened this way.

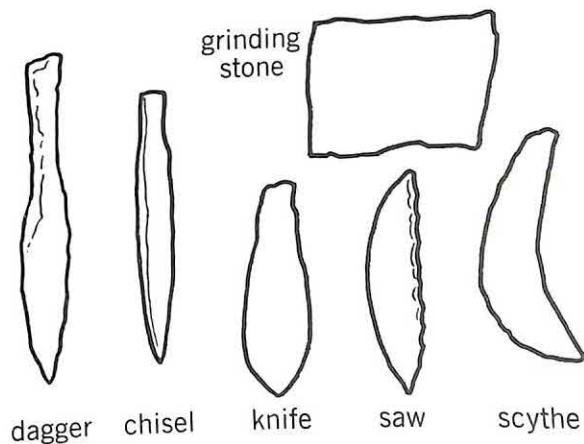
An Ancient Fire and a Great Discovery

Imagine a group of men standing around a fire heating and shaping spearheads made of “native” copper, as shown in the picture. ▲ This, of course, was a long, long time ago. Scientists believe that somewhere, somehow, in just such a situation as this, man made a great discovery.

The men built their fires with wood, of course (coal and oil had not yet been discovered). To make a hotter fire for softening their spearheads, perhaps they built a wall of stone, with openings for a draft, as in the picture. They would have used the rocks that were available around them. Some of the rocks may have been ores, containing compounds of certain metals.

A wood fire can become very hot. Imagine that some of the rocks used next to the fire contained copper ore. The ore might have been cuprite (kyōō'prīt), which contains the compound copper oxide. In the case of an iron ore, the compound might have been iron oxide. Imagine that in this particular ancient fire the rock contained a copper oxide ore.

Perhaps, then, the discovery of copper was accidental. To see what may have happened, try the investigation on the next page.



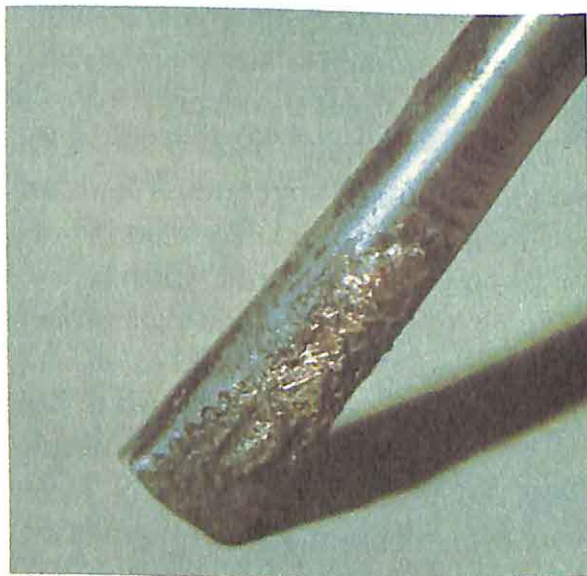
AN INVESTIGATION into Getting a Metal from Its Compound

Needed: some black copper oxide; a hot flame from a Bunsen burner or an alcohol lamp; rubber tubing; a blow pipe; tongs

Take up a bit of the copper oxide in the tongs. Ask your teacher to light the Bunsen burner and to adjust it to get a good blue flame. Then your teacher can hold the piece of copper oxide in the flame with the tongs. ■ Soon the tongs become red hot. ● After a while, they can be opened slightly to allow even more heat to reach the copper oxide, which should stick securely to one side. After several minutes of direct heating, the tongs can be placed on a piece of tile to cool. When the tongs are cool enough, scrape some of the black coating from the copper oxide. Does red, shiny copper appear? ▲



Additional Investigation: Repeat the same investigation, only this time use a piece of green copper carbonate (malachite [mal'ə-kīt], another copper ore). Do you again get pure copper? What else is given off?



The Discovery

Imagine the surprise of the ancient men to find, after the fire had died down, that there were beads of copper on some of the rocks. The rocks were deep down in the fire, where the temperature had been very high. The copper must have come from common ordinary rocks.

In this way a great discovery was made. Apparently, or so ancient man may have reasoned, all one has to do is to build a hot fire near a copper ore, and copper will be found after the fire dies down. The fire must be very hot. Really, a *blast* of fire is needed. Ancient man was no chemist, yet he learned how to obtain copper before he knew about atoms and molecules.

Later on, man learned that this fire-formed metal could be used for purposes other than for the tips of spears. He learned it could be formed into pots and pans. Many thousands of years later (8,000 to 10,000 years later), man learned that copper could be made into wire to carry an electric current. He learned this even before he understood the concept that an electric current is a flow of electrons in a conductor or the reasons why copper is a very good conductor.

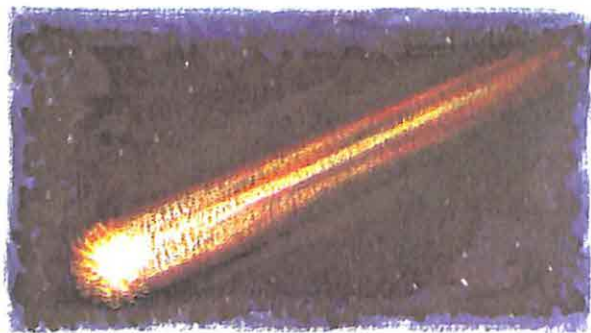
Other metals, such as iron, lead, and mercury, may also have been separated from their ores in some of those early fires. Scientists are not completely sure. After all, ancient man did not leave a written record. The alphabet had not yet been in-

vented. We do know, however, that, somehow, early man reasoned that when some kinds of rocks were heated enough, they would yield a metal that was useful in his daily life. He learned by accident and by experience and observation. His *observations* led him to imitate the natural processes and to invent others.

From what we can guess, early man did not set up an investigation as did Charles Hall or as a modern scientist would do. Early man knew *how* to extract the ore, but an understanding of *why* metal could be obtained from the ore was to come later. Understanding could come only after man had learned enough to build a concept of the structure of matter.

Copper first began to be used about 8,000 years ago, probably in Egypt. No one knows exactly when or how it was discovered, but copper was mined on the island of Cyprus about 5,000 years ago. ■ Cyprus was then known as the Copper Island.





meteor fireball



meteorite

On the basis of present evidence, scientists are certain that copper was used long before iron. Perhaps man had selected certain stones for the floor of his hearth because they were brightly colored—blue, green, reddish, or brassy (the colors of copper compounds). In the lower part of the wood fire the temperature was high enough to melt the metal, which was later found in the ashes. It may be well to note here that the invention of the hearth was an important part of this discovery.

About 3,000 (or perhaps 5,000) years ago, iron began to be used. Some scientists believe that the first iron to be used may have come to the earth from outer space as meteors to form meteorites. Meteorites are made primarily of iron together with a few other substances. ■

Trial, Error, and Success

Once man began to understand that he could win (separate) a metal from its ore by using heat, he began to heat many different kinds of ores. You might think of it this way. Remember the way you tried tying the bowline knot (Unit One). Perhaps you tried it one way, and then another, and failed. Then another trial, and there was success. *Trial and error. Trial and error. Trial and success!* Much of our learning is achieved in just this way, by trial and error.

Early man may have heated many different ores, and by trial and error, found that heat alone worked on some ores and not on others. In his trials, he found also that a certain temperature was needed for copper ores; a higher temperature for iron ores. Man had to learn by trial and error until he discovered the reason for his failure or success. Once man learned that heat could separate certain compounds, he could use a better method than trial and error. He could base his trials on reason, that is, on a concept of *how* heat could be used to separate metals from their ores.

Let us see how understanding of a concept does away with trial and error and helps man to *plan* his investigations and inventions.

It was ancient man who discovered how to separate certain metals from their ores. Copper is a metal which can be separated most easily. It is extracted from ores containing copper oxide and copper carbonate.

Early man knew nothing about the composition of compounds. We do, so we reason as follows: Somehow, the atoms in copper oxide are not held as tightly as the atoms in some other compounds. A very hot flame can separate the copper from the oxide.

The oxygen leaves the copper and combines with certain of the hot gases in the flame. The oxygen is then carried away in the hot gases.

Iron is a different matter, as you shall see. Nevertheless, ancient man did discover a way of getting iron from its ore (by accident, or so scientists think). Perhaps he tried heat on all kinds of rocks and found that it worked with some and not with others. Thus, from his observations, he began to gather information. Once again, no doubt, a chance observation led to an important discovery, and then to another invention.

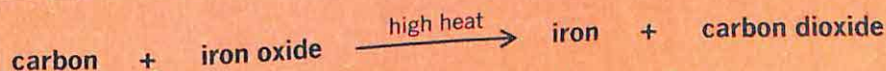
Perhaps man realized that green wood cannot reach very high temperatures or that a hot flame was not enough. He may have observed that incompletely burned wood leaves a light porous residue that we call charcoal. Perhaps he found, by accident again, that adding charcoal to his fire made the fire hotter and helped to separate some metals from their ores. Observation is important to invention.

Man's next step, then, was to imitate the natural process and to make charcoal. Charcoal is mainly carbon and is very effective in separating some metals (particularly iron) from their ores. How is this possible?

Suppose the ore is the oxide of a metal, such as iron. It is then possible for the oxygen in the oxide to combine with the carbon. In this way, carbon dioxide (a gas) is formed, and the metal is left behind. ●

He probably did not learn this the first time. He probably observed *again* and *again* and *again* that he could separate the iron *only* when he had hot glowing carbon (wood coals) in his fire. He learned then to make iron this way: First, get a very hot fire and let it burn until the wood is thoroughly charred, that is, carbonized. Then, add the iron ore. Perhaps he found that blowing air into the fire would help to get a higher temperature. Here again observation was important to progress. Observing the effect that wind has in making a fire burn faster probably led to the idea of an artificial draft.

Oxygen cannot be removed easily from iron oxide by the hot flame alone unless the temperature is extremely high. It can be removed much more easily when the oxygen acts with the carbon to form carbon dioxide (CO_2).





Ancient man found this out by trial and error; but he did not understand it. Modern man, as a scientist, does understand because he has discovered the differences in the structure and behavior of the atoms and molecules of different substances.

Copper oxide, for example, gives up its oxygen easily, either to carbon or to the hot gases in a flame. Study the figure to find what you would get when the oxygen combines with carbon. ■ The metal is thus freed in its pure state. Other common copper ores contain the sulfides and the carbonates of copper.

When green copper carbonate is heated, carbon dioxide is given off and part of the ore is changed to copper oxide. ● The copper oxide can then be broken down to pure copper by the hot gases in a flame. Carbon dioxide is again given off.

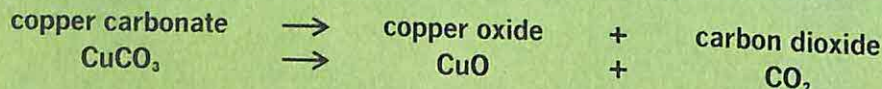
Ancient man did not know that each pure metal (or each pure element) is made of its own particular kind of atom. He did not know that pure iron is an element containing only atoms of iron; but there were

many things that he did know. He discovered metals and the ways of working metals which are still the basis of modern metallurgy. He invented metal furnaces and learned to make charcoal. He combined copper and tin to form bronze, even before he understood the concept of the atom. Understanding the concept was to come later. When man did make this discovery, he was able to put the concept to good use. He was able not only to get iron from its ore but to combine metals in ways that ancient man could not have imagined.

In the process he developed one of the important tools in the technology of making iron and steel. That invention was the blast furnace.

The blast furnace is a vast improvement over rebuilding the fire each time; but remember that it was the prehistoric inventors who extracted the first metals and built the first tools.

Through an understanding of the structure of matter, man was able to build a technology for making iron, one of the most important metals in our civilization.



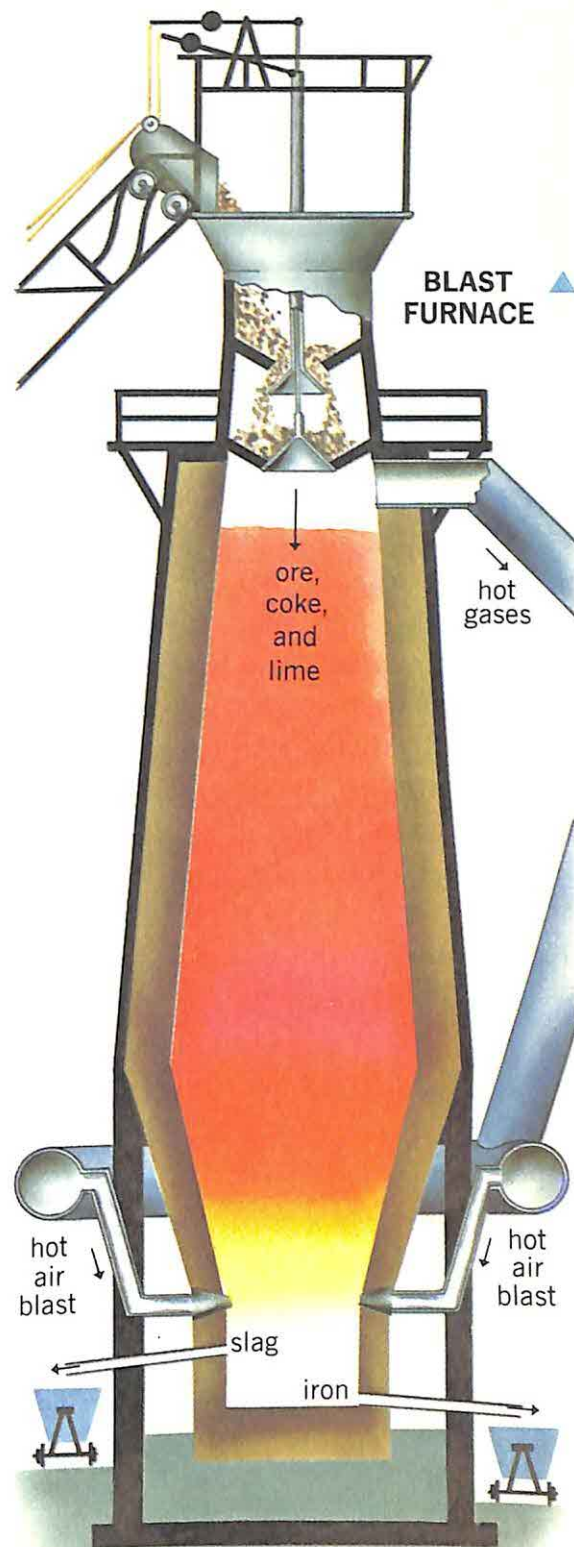
Furnaces for Making Iron

Look at the picture of the huge blast furnace, the kind used today for extracting iron. ▲ Several different things go into the furnace, but you should now know which two materials *must* go into it. They are iron ore and carbon. The carbon is in the form of coke rather than charcoal. Coke is carbon which is made from coal in a way similar to that in which charcoal is made from wood. The materials which go into making iron are called raw materials. Iron ore, coke, and limestone are the raw materials for extracting iron and making steel.

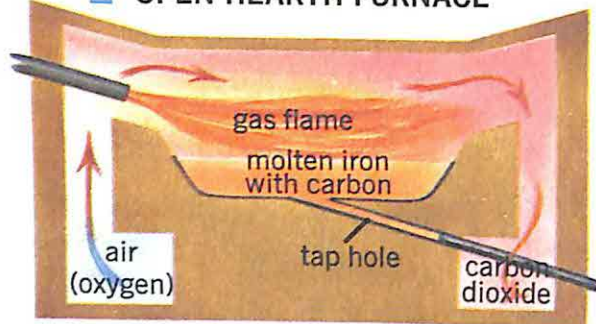
The coke and the iron ore are heated to a very high temperature in the blast furnace. Hot air is blown in at the bottom to increase the temperature. Carbon from the coke combines with the oxygen in the iron oxide. Carbon dioxide is given off and molten iron is left. This hot molten liquid pours out through another opening at the bottom of the furnace.

If you live in, or travel through, Pennsylvania or Indiana, you may see many huge blast furnaces like the one shown. Iron is reduced in them, and, even more important, modern man has learned to make steel from the refined iron.

Steel is iron that is refined by burning much of the carbon and other impurities out of it and then adding a measured amount of carbon to it. When iron is heated in a blast furnace, much of the carbon remains in the iron. Crude iron is brittle; it breaks

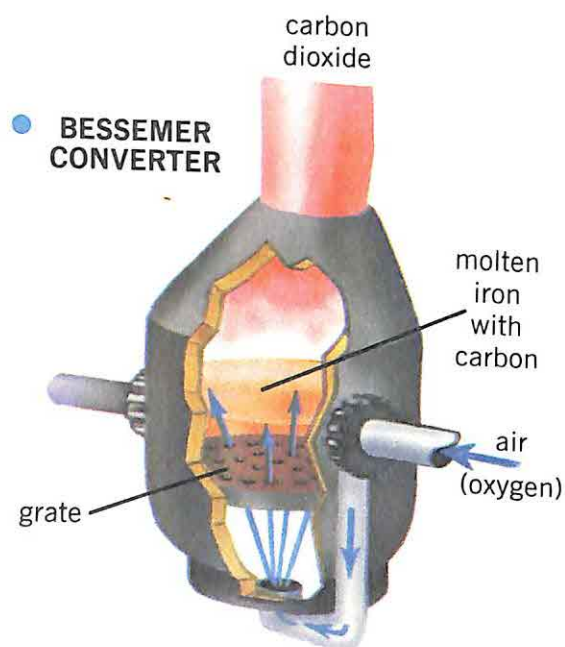


■ OPEN HEARTH FURNACE



easily because it contains leftover carbon. Most of this carbon is burned off in any of several types of furnaces. ■ The most exciting to watch is the Bessemer converter. ●

Fifty years ago, many of the items that people used were made from an iron called cast iron. It was not satisfactory for many purposes. Steel is much better; it is stronger. Today, most of the iron used is in the form of steel. Steel is made stronger by adding other materials and by heat treating; it adds strength but not weight.



Iron in the Earth

Much of our iron comes from the Great Lakes region. In the hills near Duluth, Minnesota, a city on Lake Superior, is the Mesabi range.

The iron in the Mesabi range is mainly an iron oxide. It may once have been pure iron, but all iron that is exposed to the air soon combines with oxygen to form iron oxide (rust).

In the Mesabi range, the reddish iron ore is scooped out of an open pit. ▲ Then it is shipped to a refining plant to be made into iron and steel.

There is iron ore in every state in the United States, and it can be found in almost every country in the world. The most important iron ore regions are Minnesota, Michigan, Wisconsin, and more recently, Labrador. Almost four out of five tons of iron ore mined in the United States have come from the region around Lake Superior.

Advancing the Technology of Steel

Chemists and chemical engineers have discovered that metals can be given different properties by adding other substances to them. This special use of substances had to wait until man understood what a substance *is* and what *it is made of*. Once man knew that a pure element was made of only one kind of atom, he could *combine* substances to produce new kinds of compounds. Once he could produce pure substances, he could study their properties. He could then combine substances having different



properties to produce new kinds of metallic substances called **alloys**.

Alloys are combinations of different elements, one of which must be a metal. An alloy has properties different from either of the two elements which were combined. For instance, the chemist adds nickel and chromium to steel to produce a metal called stainless steel that does not rust.

Study the table below. ♦ Do you have any such alloys at home?

Without iron and steel man could not have built tall buildings and bridges. A steel bridge can **corrode** (kə-rōd') if it is not covered regularly with a protective coat of paint. When it is exposed to air, iron combines with oxygen to form the compound iron oxide, or rust. Thus, steel bridges

TABLE OF COMMON ALLOYS

Alloy	Metals contained	Uses
babbitt	tin, antimony, copper	linings for bearings
brass	copper, zinc	cookware, ornaments, fireplace sets
bronze	copper, tin	statues, guns, ancient tools
coin silver	silver, copper	U.S. coins 10¢ and up
dentists' amalgam	copper, mercury	fillings in teeth
german silver	copper, zinc, nickel	jewelry
nichrome	nickel, chromium	electric wire
nickel (coin)	nickel, copper	U.S. 5¢ piece
pewter	tin, copper, bismuth, antimony	early American utensils
solder	lead, tin	joining metals
stainless steel	iron, chromium, nickel	knives, kitchen utensils
white gold	gold, nickel, zinc	jewelry, watch cases

need to be painted regularly to keep them from rusting. To see the effects of rusting, or **corrosion** (kə-rō'zhən), try the investigation on the opposite page.

Perhaps you have some metals in your pocket. Are they pure metals? For instance, is a dime pure silver? Is a penny pure copper? Is a nickel coin pure nickel? Or are they alloys? How could you find out?

Ancient man learned about metals. Perhaps by trial and error, he learned to make bronze, an alloy of copper and tin. He learned about gold, silver, copper, and iron, and the uses of each.

From the beginning, the techniques for working metals developed in three distinct directions. The first was the extraction of the metal from the ore by the use of furnaces. The second was the refinement of a metal by hammering it, and the third, the casting of the pure metals into molds to obtain objects for everyday use or works of art. But something else was important.

If man had confined himself to scratching at the earth's surface, the industry of metals would have ended. He had to dig into the soil and rocks to search for the ore; he had to learn to recognize it. He had to find some way to mine it. In short, in order to be a metal worker, man had to become a miner. He had to learn to light his way, to pump water from the mines, and to bring the ore to the surface.

From chance discoveries man introduced a vast industry; but as he ad-

vanced, he invented tools and techniques. His progress became more the result of planning than of chance.

The principle of alloys was discovered by chance and has remained unchanged through the centuries. Some primitive alloys survive today. Today, however, man knows a great deal more about the chemistry of metals, their microscopic structure, and their properties. He produces hundreds of different types of alloys ranging from the bronzes and brasses to the alloys of steel.

The first metals to be used, apart from copper which was often found in its natural state, were gold and, perhaps, silver. Iron came last, because it required higher temperatures and more difficult techniques.

By the middle of the nineteenth century, the groundwork had been laid for Henry Bessemer to design his converter. The production of steel and iron became easy and economical. Metallurgy changed from craftwork to a large-scale industry.

Early man was a discoverer, but he learned mainly by trial and error. Nevertheless, he observed his environment and slowly he learned how to change his environment. Later, much later, he was to become a scientist; and, as a scientist, he would be able to plan investigations.

At the end of this book there is a section titled, "**The Art of Investigation**" (page 409). Why not take a look? You may want to do an investigation on your own soon.

AN INVESTIGATION into How Fast a Tin Can Rusts

Needed: two tin cans; a nail; a damp cloth

Remove the covers from two used cans. Be careful not to cut yourself on rough edges. Wash both cans. On *one* can make five or six long scratches with a nail. ■ Make the scratches deep to remove the tin coating.

Now set the cans aside and cover them loosely with a damp cloth. ● Look at them every day. Keep the cloth damp. Do you see a reddish-brown substance where you scratched the tin? ▲ What is the substance? What is the metal in the can that has been protected by the tin plating?

Why is tin used to protect the iron?
CLUE: Rusting means the combination



of a metal with oxygen. Does tin combine more easily with oxygen than iron?

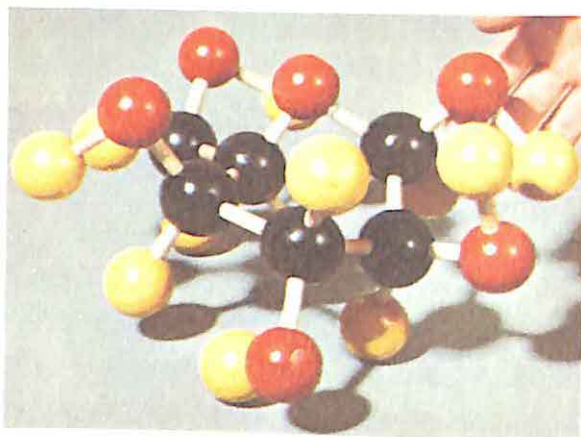
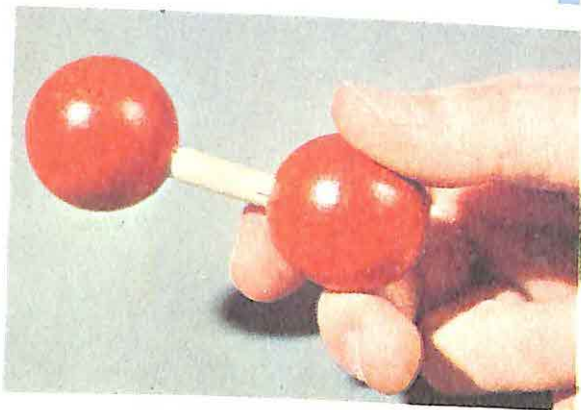
Additional Investigation: In the library look up the term "galvanized." Which metal is used to protect a galvanized pail? What metal underneath is being protected?



More New Materials

Already the chemical engineer is beginning to replace many metals with other materials. He can do this because he has learned that all matter is made up of *elements* and *compounds*, so he can recombine the elements into newer compounds. Remember that pure gold, silver, and iron are *elements*. Elements contain only one kind of atom. Compounds are made of more than one element. Each compound contains two or more different kinds of atoms that are combined chemically. The pictures show models of two different molecules. ■ ● Which model represents an element? Which model represents a compound?

Man is competing with nature. With his knowledge of chemistry he produces materials which have never before existed on the face of the earth. He is engaged in an industrial activity that affects every part of day-to-day living. He brings to us a whole range of new substances that are manufactured into a variety of articles, from the fountain pen to the telephone.



Understanding and applying the concept that matter is made of atoms and molecules has produced this whole new world of synthetic substances.

The chemist has learned how to produce many new compounds in the laboratory. Some of these new compounds have the properties that he wanted from metals. They have *strength*; they *can be molded* into different shapes; and even more than that, they *do not rust or corrode*.

These new substances that man has developed are not used to build bridges, as yet, but you have already used them for other things. Some of them replace china dishes. Cups, saucers, and plates made from such materials are unbreakable. Furniture has been made from these new substances. Do you know what they are? The new class of substances is called **plastics**. Plastics opened up a new field of technology.

How many different kinds of plastics do you use at home? And for what purposes? dishes? radios? clothing? gadgets? furniture? automobiles? the knobs on your television set?

BEFORE YOU GO ON A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

- B.** Write a paragraph or two on this topic: Blast Furnaces.

USING WHAT YOU KNOW

1. In your lifetime man began to explore space. He built rockets and spaceships.

The concepts which help us understand gravity and motion of rockets and satellites were developed by Isaac Newton in the seventeenth century. Why did we have to wait so long to send John Glenn and other astronauts into space?

2. We see modern utensils—especially kitchen utensils—being developed of metals like aluminum, stainless steel, or from synthetic materials like plastics.

a. Why is it useful to have kitchen utensils made of these materials?

b. Why is some metal kitchenware coated with enamel?

c. Why were kitchen utensils in the sixteenth and seventeenth centuries made mainly of copper and its alloys?

ON YOUR OWN

1. Present a report to your class on the history of plastics. Include something about their chemistry in your report.

2. Make a similar report on silicones (sil'ə-kōnz).

4. The Uses of Ideas and Tools: New Fibers

Man makes use of what he finds. When he does not find what he wants, he tries to invent a new material. Ancient man, by trial and error, found a way to make a metal stronger than copper. He made an alloy of copper and tin, an alloy called bronze. He made bronze before he understood the concept that matter is made up of particles and that these could be combined in a variety of ways. Modern man, knowing the concept, invents hundreds of alloys.

Ancient man worked the metals he found and invented *some* alloys. The scientist, with a knowledge of a concept, has a better way to make discoveries than by trial and error alone. Knowledge of a concept helps a scientist or an engineer to plan his investigations and his inventions. A good example is man's invention of plastics and new fibers. The investigations which led to the invention of new fibers were done in a modern laboratory. To a large extent the trials and errors of ancient man were eliminated. The story goes somewhat like this.

Improving on a Moth

Perhaps you will be surprised to know that man was not satisfied with the product of a moth. This particular moth had served man for many hundreds of years, even before Marco Polo traveled from Italy to China about 650 years ago.

What happens inside the cocoon of a moth? Before we answer, let's go back and take a look at the life history of a moth.

The adult female moth lays eggs which develop and hatch into caterpillars. ■ A caterpillar, or **larva** (lär'-və), as it is called, does not look like an adult moth. The caterpillars, or **larvae**, spend most of their time feeding on green leaves. A larva of this particular moth eats the leaves of the plant, the mulberry plant, on which it hatches. Then, when the larva is full grown, it begins to spin a **cocoon** around itself. The cocoon is useful to the moth, for in it the adult moth develops; but man had other uses for the cocoon of the silk moth.

Have you ever seen a moth larva spin a cocoon? or a spider spin its web? The spider makes a substance inside its body that comes out of the spider as a liquid. In the air the liquid becomes a thin silky thread.

The moth larva makes a thin silky thread too. It spins its web around itself and makes a cocoon. There it rests for a time. In this stage, the moth is a **pupa** (pyōō'pə). In the cocoon the pupa changes and it emerges some weeks later as an adult moth.



■ THE SILK MOTH



Thousands of years ago, the Chinese and Japanese learned how to unwind the thread from the cocoon, and how to produce silk thread. The picture shows the cocoons being dried. ■ This kills the pupae which would break the silk filament of their cocoons, if they were allowed to emerge. Of course some of the pupae are allowed to become moths in order to produce more silkworms. After many years the use of silk spread over the world.

Silk is a beautiful and strong material, but it is expensive; silk moths cannot be grown everywhere. It takes a long time for moths to develop from eggs to caterpillars to cocoons to silk threads. Still only the silk moth can produce silk thread. Man was unable to invent something as good as the silk that came from the moth. Trial-and-error methods did not work to produce a good substitute.

Man Tries to Imitate

The origin of cotton has never been definitely determined; but it has been indicated that cotton cloth was being produced as early as 1500 B.C.

Man learned very early to use the fibers of the cotton plant. He picked the cotton boll and for hundreds of years removed the seeds by hand. This was very expensive labor. Removal of the seeds by hand was so difficult that it required a day for one person to clean a pound of cotton. Eli Whitney went to work and in ten days produced the cotton gin, a machine which separated the fibers from the seeds very easily. He patented the machine in 1794.

Cotton is one of the most valuable of all plants. The uses for its fiber are so varied that it is by far the most important of all textile fibers. Today, however, many synthetic fibers are being used in the textile industry.

Still, in 1794, the concept of the composition of matter was just being developed. The way atoms and molecules combined to form new compounds was not yet fully understood. It wasn't really until the 1850's that the science of chemistry began to develop rapidly.

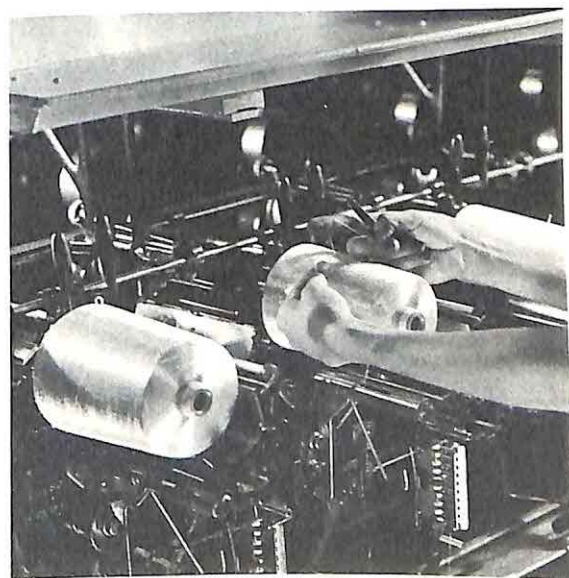
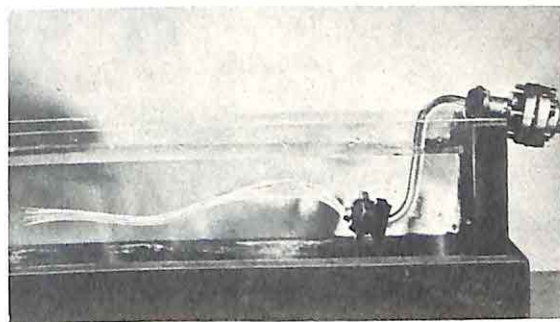
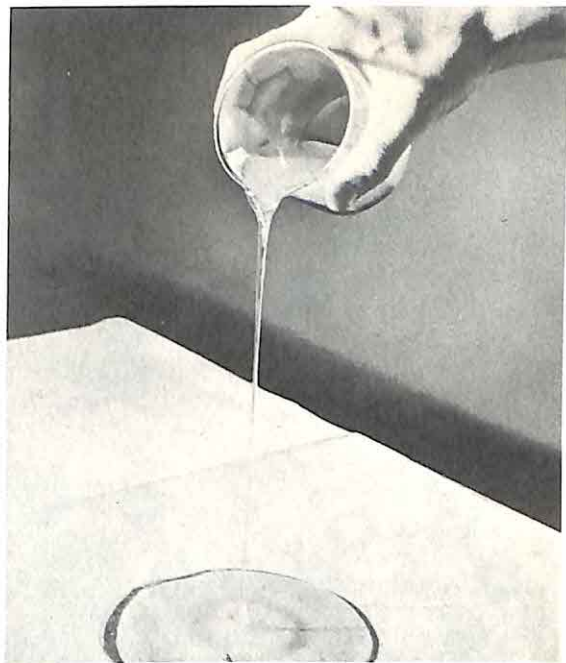
As chemists learned more about ways of combining molecules, it was natural that they should turn to a study of substances like silk and cotton. They found that they could change cotton into a thread that had *some* of the properties of silk.

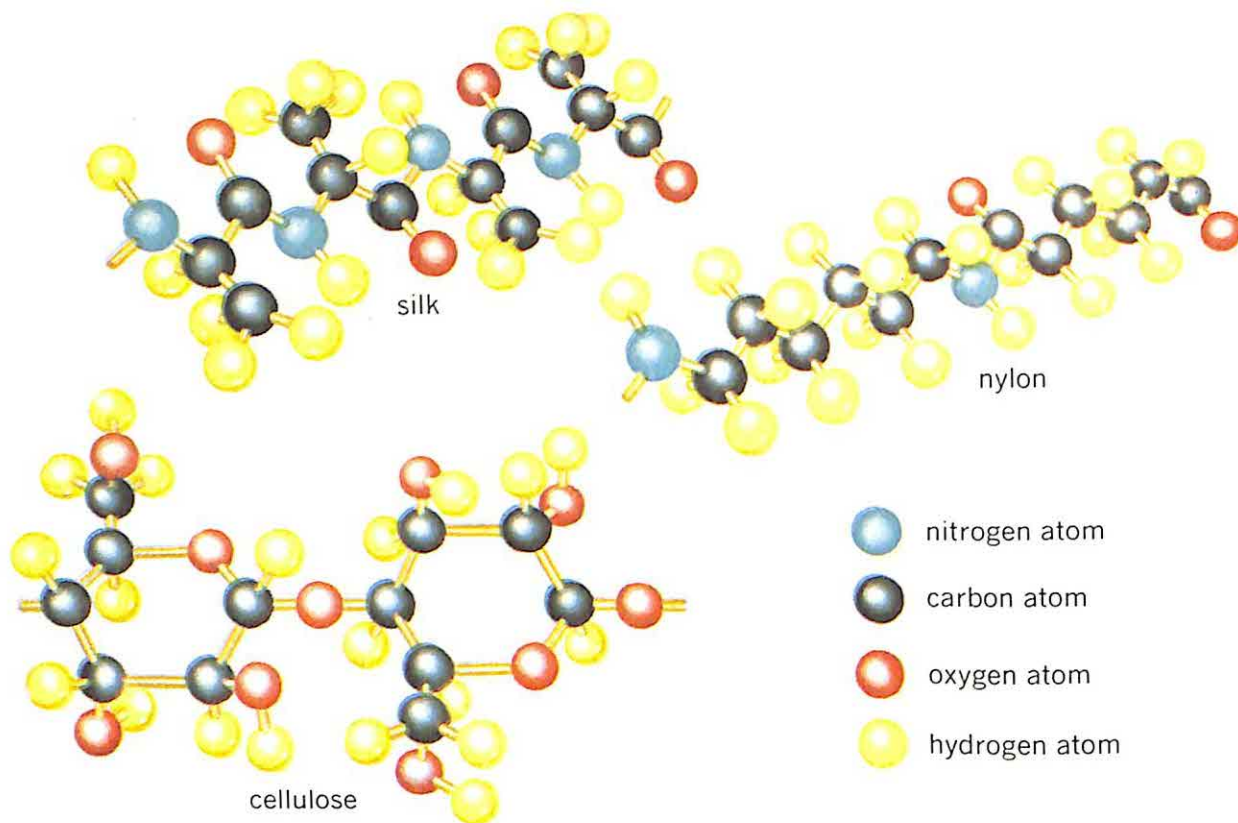
One way the chemists found is to dissolve cotton in sodium hydroxide. Then, as in the picture, the dissolved cotton is pressed out through tiny holes into a liquid. It hardens into a fiber which is called **rayon**.

Rayon was first known as "artificial silk" and was considered a substitute for the luxurious fiber. It could be made at less cost.

Spinning a thread by pushing a liquid out through tiny holes is very much what the silkworm did; but rayon has never really had many of the properties of silk. It does not wear as well nor does it take dyes as well as silk.

The chemists, in creating synthetic fibers, decided that the thing to do was to start at the beginning; that is, they decided to start with the atoms which make up a fiber like silk or cotton. For instance, the fiber of the cotton plant is composed of **cellulose** (sel'yə-lōs), a substance containing





carbon, hydrogen, and oxygen. The picture shows a model of a molecule of cellulose.■ There is, however, at least one more element besides carbon, hydrogen, and oxygen, in a silk fiber. That element is nitrogen, and it is shown in the model of a molecule of silk.■

After many years of investigation in the laboratory, chemists invented a strong fiber made up of *carbon, hydrogen, oxygen, and nitrogen*; but it was not silk. It turned out to be better for many uses. This fiber has many properties like those of silk, but it is much stronger. You have already worn clothes made of this fiber—**nylon**. Look at the picture that shows a model of a nylon molecule.■

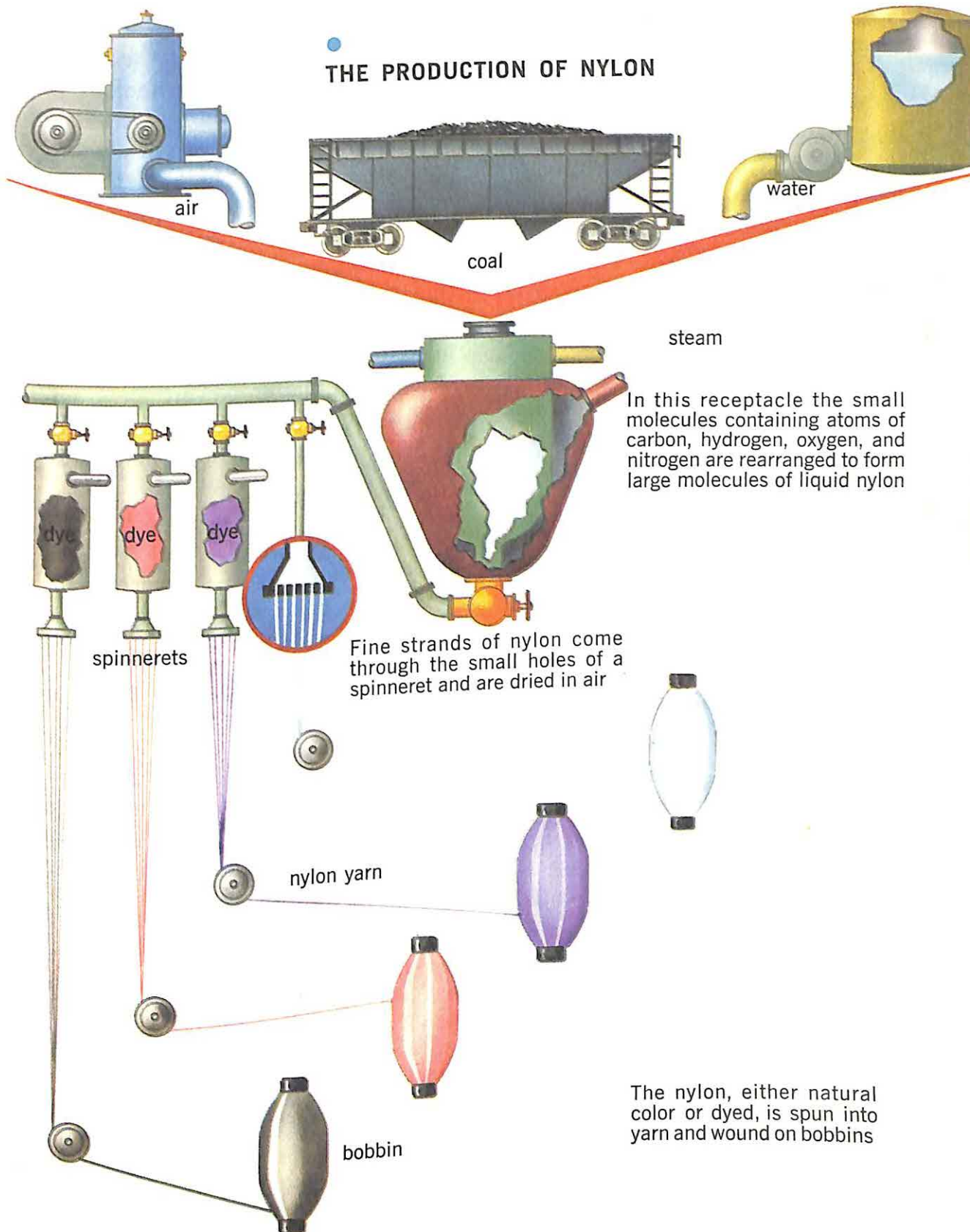
Is it more like the molecule of silk or of cellulose?

The raw materials for the making of nylon are all around us. What is a source of carbon? *Coal*. What is a source of hydrogen? *Water*. What is a source of oxygen and nitrogen? *Air*.

Coal, water, and air are the raw materials from which nylon is made; and the usefulness of nylon seems to be unlimited.●

Man's need for textiles is constant. Ever since he stopped using animal skins for clothing, textiles of one kind or another have been an essential part of civilized living. To what extent the chemist's tube will produce new and better fibers is for the future to determine.

THE PRODUCTION OF NYLON



Ancient man could not have made rayon and nylon. Ancient man did not know about the building blocks of living things, and he did not know that plants made cellulose from carbon, hydrogen, and oxygen. He did not know that animal fibers were made of these elements plus nitrogen. More than that, ancient man did not even know of the elements on earth. He did not have the ideas, and he did not have the tools.

Again we see how science and technology go hand in hand. This time, however, invention had to wait until scientists had developed the concepts

which explain the structure of matter. This was not the way with the discovery of iron. The technology of iron, copper, and gold was well on its way before the science of chemistry was developed. In fact, the invention of the technology of iron gave scientists the facts from which to reason out the structure of matter. On the other hand, the technology (that is, the invention) of new fibers had to wait until scientists understood the structure of matter. Nevertheless, science and technology go hand in hand, although one may advance before the other.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Before man developed the concept *matter is made of atoms and molecules*, he had invented

- a. rayon
- b. alloys

2. Many times, man used the substances and materials around him. He developed simple ways (a simple technology) of using these materials. In this manner, he developed ways of using

- a. cotton
- b. nylon

3. In order to get silk, man had to understand the ways of the

- a. moth
- b. machine

4. Man could not invent new fibers such as nylon until he understood how elements and compounds combine. In other words, man had to wait until the

- a. concepts were developed
- b. machines were developed

5. To invent new fibers such as nylon and Dacron man had to know more

a. alchemy

b. technology

B. Write a paragraph or two on this topic: A New Technology: Producing New Fibers.

USING WHAT YOU KNOW

If chemists and chemical engineers continue to develop a science which enables them to combine elements in different ways and a technology to use this knowledge, we can expect man-made materials to replace those which are made by animals and plants.

Which of these materials can now be replaced by new materials: cotton; silk; wool; linen; wood; horn (from horns of animals); ivory (tusks of elephants); leather (hides of animals)? Add any others you wish.

ON YOUR OWN

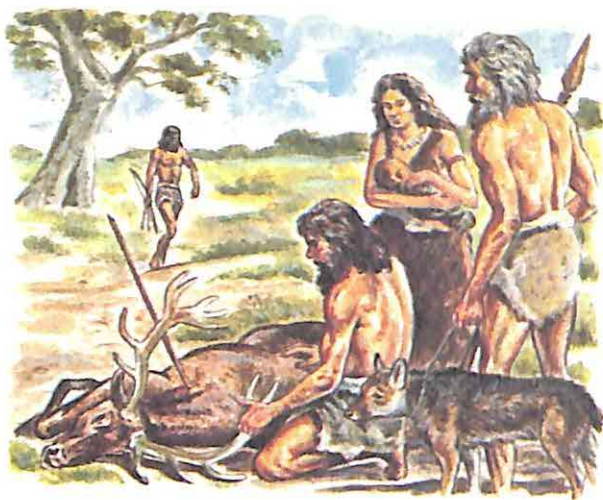
If you do not know of new materials which could replace any of those listed, you can find some by doing research in the library.

5. The Main Concept: Changing the Environment Through Science and Technology

The earth has been here for many millions of years. The riches of the earth's crust have been here as well. It is only in the last 5,000 years that man has really learned to use them; but man has learned to make use of and to change his environment through the partnership of science and technology.

Animals and plants must live in their environment. If the environment changes, the animals and plants must adapt to the changing environment, move on to a new environment, or die and become extinct.

On the other hand, man changes his environment to suit his needs. He can now live under water for months in a nuclear submarine or he can live in a spaceship. He can control his environment by using new ideas to build new tools, or new machines, or new materials.



Early man fed on the earth's plants and animals. He clothed himself in animals' skins. When he discovered fire, he learned to burn wood and to cook his food. Early in his life on this planet man was a food-gatherer. ■

He used stone to make clubs and spears, and soon tipped his spears with stone spearheads. Ten thousand years ago, man learned to tame animals. The dog followed him wherever he traveled. Soon he had other animals, like the horse, in his camp. ●



He learned to plant seeds in order to grow the plants he liked to eat. He became a farmer. He changed from a food-gatherer to a food-producer. ●

Then, sometime between five and ten thousand years ago, man began to win metals from the earth. He could do this because he had learned to use heat properly. He developed a simple technology by trial and error before he thoroughly understood the concepts underlying his technology. The medieval (mē'dē-ē'vəl) **alchemist** (al'kə-mist) tried to change the elements. He searched for a way of changing lead into gold. He tried many times but failed because he did not understand the structure of matter. ▲

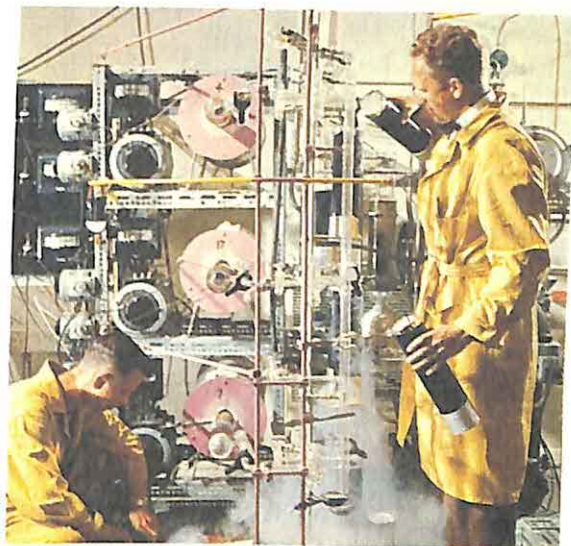
Even though the alchemists failed to change lead into gold, their work developed into the reliable chemical knowledge of today. Their experiments did produce genuine scientific information and discoveries, and the finding of many elements and compounds resulted.

After man developed the concept that matter was made up of atoms and molecules, he learned to combine these particles into new substances. He developed the science of chemistry. Technology became very complex. New substances were produced in great quantities. Man began to make wider use of the earth's raw materials. He planned his investigations. He had become a scientist. For the scientist, the laboratory became his way of life. Instead of depending

mostly on trial and error, he began to plan his investigations, to write about his discoveries and ideas, and to exchange them with other scientists and engineers. ♦ He built on the discoveries of other men as well as on his own. And so, science and technology advanced together.

The scientist spends most of his time exploring the universe and trying to find explanations (concepts) of the objects and events he sees. Mainly, the scientist develops new ideas. The engineer develops a way of doing things, a technology based on the concepts of his fellow scientists. The scientist deals with ideas; the engineer develops new tools, machines, or materials. Ideas and tools are partners in progress.

Not satisfied with cotton, man made rayon; not satisfied with silk,



♦ he made nylon. Not satisfied with the oil as it came from the earth, he developed gasoline in his laboratories. Not satisfied entirely with iron, he searched for ways of obtaining aluminum. He found ways of making hundreds of alloys.



Man uses the building blocks (the atoms and molecules) of which his environment is made. He changes them as he makes new discoveries. In this way man has changed his environment. If the discoveries of science and technology are used wisely, they can be used for a better life.

Man, as a chemist, uses his discoveries concerning the building blocks of the earth in a different way from that of other scientists, such as the biologist (bī-ol'ə-jist).

For instance, look at the giant orange shown in the picture. ■ Look at the size of the hog. ● The unusual size of both is the result of discoveries made by the biologist, not the chemist. In other parts of this book you will see how the biologist, in dealing with concepts about organisms, lengthens the life of man. You will see how the **physicist** (fiz'ə-sist), in dealing with concepts of energy, improves the ways in which work can be done.

This book is intended to introduce to you the world which science and technology have made.

In this part of the book you have read about the uses of discovery, the ones made primarily by chemists. The rest of the book will explore the uses of discovery by different kinds of scientists—the physicist, the biologist, the astronomer, and others. In each case, as you examine the uses of discovery, you will see how man (as a scientist) uses his understanding of scientific concepts. This understanding is the base on which science and technology are built.

Tonight, at home, you will be able to control some features of your environment. What will you do to change your environment when it gets dark? when it gets too cold or too warm?

When astronauts and cosmonauts travel in their space capsules and spacesuits, they live in a man-made environment. ▲ As a matter of fact,



unless man takes his earthly environment with him into space, he hasn't got a chance. For here is a world that has no oxygen, no pressure, no weight. To live and work in orbital flight man must have a miracle package, a life-support system that will provide him with oxygen, water, pressurization, and complete climate control. It also must guard him against temperatures that range from near absolute zero to the reentry heat of thousands of degrees. Such a man-made environment is a product of science and technology.



Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts of this unit by doing these problems.

1. You have a five-minute talk to give on the topic "Science and Technology." Organize your talk around these questions: What are the differences between the two? How are they similar? How do they go hand in hand?

2. Nuclear energy plants, nuclear submarines, and other inventions using atomic energy were not built until the 1950's. Why not?

QUICK TEST

Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this unit.

1. Science and technology are different in that technology deals mainly with investigations which result in
- scientific concepts
 - the invention of devices

2. Science and technology are similar in that both are based on

- a. evidence from investigation
- b. ideas arising from argument

3. The launching of Telstar, which is a relay station for television, and the building of the X-15 rocket plane were mainly the work of

- a. scientists
- b. engineers

4. One of these metals was not used by ancient man. Which one is it?

- a. copper
- b. steel

5. Of these, which came first:

- a. the making of iron
- b. the development of the concept that all matter is made of particles

6. Of these, which came first:

- a. the making of silk
- b. the making of nylon

7. Which of these is more rust-proof:

- a. iron
- b. aluminum

8. Better insulators are usually the result of

- a. understanding the concept of kinetic energy
- b. trial and error

9. We now accept the concept that all matter is made up of particles. Suppose we find that the matter on the moon is made up of the same kinds of particles as the matter on earth. This would:

- a. not surprise us
- b. surprise us

10. In the main, we now accept the concept that the particles of matter are in motion. Because its molecules are in motion, we expect a liquid to evaporate. If it does not,

- a. this should surprise us
- b. it should not surprise us

FOR YOUR READING

These books will help you learn more about the way science and technology go hand in hand.

1. *Engineers Did It*, by Duane Bradley, published by Lippincott, Philadelphia, 1958.

This is an interesting account of the world's great engineering feats. There are simple explanations of the scientific concepts underlying them.

2. *Aluminum, the Miracle Metal*, by C. B. Colby, published by Coward-McCann, New York, 1960.

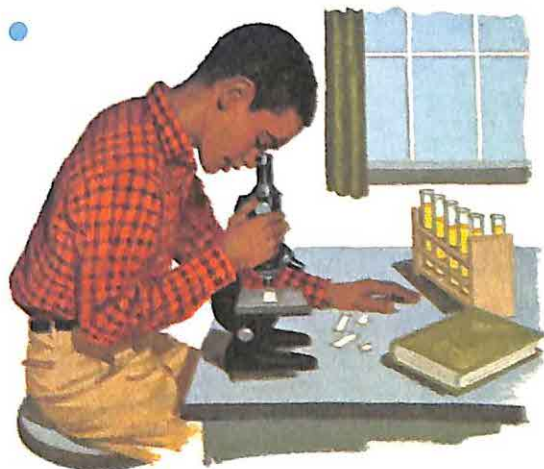
Here again is an example of the way science and technology go hand in hand.

ON YOUR OWN

Now is a good time to begin to practice the ways of the scientist. Go to the end of the book, on page 409, where you will find a section titled, "The Art of Investigation." There you will find sections titled:

1. Analyzing an Investigation
2. A Word About Words—And a Word About Acts
3. Investigations—On Your Own
4. Selecting Your Own Problem for Investigation

The investigations which are described are ones to which there is no answer in this book, but by designing a proper investigation you can make a discovery yourself. Examine these pages now. Then select a problem to investigate on your own. ■ ●



CONCEPTUAL SCHEME

Living things are interdependent with one another and with their environment.

Unit Three

IDEAS AND TOOLS: FOR LONGER LIFE

(Text pages 98–145)

UNIT CONCEPT

Living things are adapted by structure and function to the environment.

A Preview of the Concepts

Pupils investigate a world of living things about them which they cannot see. They begin to appreciate that microorganisms, including the viruses, are adapted for living in many kinds of environments. Man uses his understanding of interdependence to provide a physical or chemical environment unfavorable to organisms that may harm him, and a favorable environment for those that can help supply his needs.

A VIEW OF THE UNIT

In Unit Two, the pupils studied how man uses concepts in science to fashion better materials. In this unit, they see how concepts of science are applied to fashioning tools for a better life. This means that they now investigate a specialized branch of science, bacteriology—or microbiology—that is concerned with maintaining health.

Pupils will be unable to see individual bacteria in their investigations unless you are fortunate enough to have a microscope with a magnifying power of 400× or better. Even then, only the larger kinds of bacteria might be visible. Until relatively recently, scientists had to investigate most microorganisms from the effects they produced; high-power light and electron microscopes had not yet been invented. In this unit, pupils will investigate the growth of molds and bacterial colonies and, from what they see, develop the inference that molds and bacteria are extremely small microorganisms that reproduce and carry on all the life activities. They will see that altering the environment of these microorganisms can affect their functions and even destroy them. Of course, the effects of environment on the growth of microorganisms were known before Louis Pasteur and Robert Koch performed their experiments that verified specific microorganisms as the causes of diseases in plants and animals, or before Alexander Fleming discovered penicillin, or Jonas Salk and Albert Sabin developed vaccines for the polio virus.

In earlier work in science, especially in *Concepts in Science 5*, your pupils investigated the adaptations of their own physical structure that enable them to live in many kinds of environments. In Unit One, they also gained a greater understanding of the uses of the brain as an adap-

tation for learning to control the surroundings. But man's battle for control over his environment has not been easy. More had to be learned about how the body afforded an environment favorable for the growth of microorganisms.

When it was known that infections on the body surfaces were caused by bacteria, scientists set themselves the task of finding antiseptics that would control the bacteria without damaging body cells. The first antibiotic for control of microorganisms in the body was not discovered until 1928 and, even then, not developed until World War II. This and other soon-discovered antibiotics were only temporary in their effect; infection had to be known or suspected before any newly discovered antibiotics were useful.

It was also known that the body developed chemical defenses as a result of vaccination, but the method of attacking the problem of controlling most viral infections by means of a vaccine had to await the invention of the electron microscope so that the structure of the microorganisms that caused disfunction in the body could be studied. Vaccines give long-lasting immunity against invasion by specific microorganisms, among them certain viruses. Preventive medicine has made great strides in recent years, as science and technology have worked together to give man longer life.

In modern living, with means of rapid transportation, food and water may travel long distances. In their travels they may pass through many different environments and could be infected by many different microorganisms. The need to prevent contamination from source to dinner table has resulted in new techniques for sealing-in food values and sealing-out contaminants. Federal, state, and local agencies cooperate. As a result, food poisoning and bacterial diseases, such as cholera and typhoid, are relatively unknown.

These are among the major concept-building areas that the pupils will study in this unit. Their chances for a longer life are made possible because medical technologists have applied the major concept in science that living things are interdependent with one another and their environment. Note that the method of attack has been either to remove the microorganisms from man's environment or to make the environment of the microorganisms unfavorable for their growth and development.

This unit encourages the use of the microscope for the investigations in the pupil's textbook and in the materials designed to accompany the textbook. Since a microscope is an expensive and delicate instrument, you may wish to introduce the unit by a day's practice in its use.

If you permit the pupils to carry the instrument, train them to grasp it firmly by the *arm* and place the *base* on a flat, firm support where the microscope is unlikely to tip or be knocked over. The microscope should be placed so that the arm is toward the pupil when the microscope is in use, and on a support low enough for the pupil to be able to look through the eyepiece comfortably.

Antiseptics and Antibiotics

Antibodies

Public Health Services

*Care and Use of the
Microscope*

Have the pupils practice the following steps until they can run through them correctly and easily:

1. With the *large wheel*, turn the *tube* of the microscope down until the *low power objective lens* is about $\frac{1}{8}$ of an inch from the *stage*.

2. With the eye at the *eyepiece*, turn the mirror toward a source of light, moving it until a bright circle of light is visible through the tube.

3. Pupils may be interested in seeing what a clipping from a single hair looks like under a microscope. To make the slide, they should place two or three small clippings on the slide, add a drop of water with a medicine dropper, and cover with a cover slip. This is best done by touching the slip to the drop of water and then lowering it to the slide like a hinge. Place the slide on the *stage* and fix by the *clips*. This technique is useful for most wet mounts the pupils may make.

4. Turn the larger wheel BACKWARD (counterclockwise) so that the tube is moved UPWARD until the hair is visible. The slide may need to be shifted slightly to bring the hair into the circle of light. Pupils should NEVER turn the large wheel away from them (clockwise) while looking through the eyepiece. In doing so they may lower the eyepiece far enough to crack the slide and possibly damage the objective lens at the bottom of the tube. If the tube needs to be lowered, pupils should go back to step 1.

5. Once the hair comes into view, the *smaller (focusing) wheel* may be turned slightly, either forward or backward, to focus the hair clearly. This is the only adjusting wheel which may be moved forward or backward—and then only with care.

6. To look at the hair under high power, turn the *nose piece* so that the high-power objective points straight down. A click will be heard when it snaps into position.

7. For a clearer view of the hair, turn the small focusing wheel only. NEVER use the larger wheel when the high-power objective is in place. The objective lens is very close to the slide under high-power adjustment.

8. Turn back to low power when ready to remove the slide. A click will be heard when the objective is in position.

An understanding of these parts, how they work, and the reasons for using them in the manner suggested will increase the pupils' pleasure and efficiency in their investigations. Use only soft lens paper for cleaning the eyepiece and the objective lenses to avoid possibility of scratching. And keep the microscope covered, or in its case, when it is not in use. A microscope that is properly cared for will last for many years.

Both on the teacher's pages and in the pupil's text, cautions are noted on the disposal or sterilization of culture plates or dishes that have been used for growing bacterial colonies and molds. The chances are that the colonies will be made up of harmless bacteria, but occasionally a pathogen may be introduced on the culture medium, resulting in a hazardous concentration. For this eventuality, pupils should not be permitted to touch bacterial colonies with their hands. It is best to use a

loop of wire or a needle sterilized in a flame to transfer any bacterial growth to a culture plate, and to sterilize again after transfer. Once an investigation is completed, all culture plates should be turned over to you for disposal. A little Lysol poured over the culture and allowed to stand overnight will effectively kill bacteria, and the culture plates or Petri dishes can then be cleansed for reuse.

SUPPLEMENTARY AIDS

All films and filmstrips are in full color unless otherwise indicated. Although most of the visual aids are listed at the junior high school level, they may contain much that is useful for developing the concepts in the pupil's textbook. Names and addresses of distributors and suppliers are on page F-26.

How Our Bodies Fight Disease (8 min., black-and-white), E.B.F. Shows by animation the body's three lines of defenses against bacterial disease: the skin and mucous membranes; lymph nodes and antibodies; and white corpuscles. Explains immunization. (Intermediate)

Antibiotics (14 min.), E.B.F. Recreates events that led to Dr. Fleming's discovery of penicillin, and illustrates present-day uses of antibiotics in treating diseases and in food preservation. (Junior High)

Immunization, Second Edition (11 min., black-and-white), E.B.F. Explains what immunization is and how immunity to infectious diseases is attained. (Junior High)

Our Body Fights Disease (43 frames), McGraw-Hill. Simple explanation of how nature itself helps fight disease. (Intermediate)

Antibiotics—Disease Fighting Champions (48 frames), McGraw-Hill. Shows experiments of Dr. Fleming and other scientists that led to discovery of antibiotics. Explains how these antibiotics act on disease germs and how great has been their effect in combating disease. (Junior High)

The Salk Vaccine (40 frames), McGraw-Hill. Shows the work of Dr. Jonas Salk and other scientists in discovering the viruses that caused polio and in the development of polio vaccine. Explains antibodies and vaccination. How polio vaccine is made, tested, and used today; its importance to man. (Junior High)

Work of Louis Pasteur (40 frames), McGraw-Hill. Shows the work of Pasteur; effect of bacteria; pasteurization; cause of spread of communicable diseases; use of vaccines. The first scientifically controlled test of a vaccine was made by Pasteur. (Junior High)

Starred (*) titles are especially recommended for their content and reading level. Addresses of the publishers are on page F-24.

**Above All a Physician* by Jeanne Carbonnier, Scribner's, 1961. A stimulating biography of Théophile Laennec, inventor of the stethoscope. He pursued

Films

Filmstrips

Science Reading Table

his medical practice during the exciting and difficult times of the French Revolution, which adds to the intriguing quality of the story. (Advanced)

The First Microscope by Hal Dareff, Parents' Magazine Press, 1962. Suggests the reader make a water microscope, for which directions are given, as a means of understanding a basic characteristic of regular microscopes. The wonderful—and dangerous—world of microbes is described. Particular attention is given to the work of Pasteur, Koch, and other dedicated microbe hunters. (Average)

°*The First Woman Doctor* by Rachel Baker, Scholastic Book Services, A Division of Scholastic Magazines, 1961. Paperback published by arrangement with Julian Messner. This biography of Elizabeth Blackwell, M.D., depicts, like a novel, the heroic struggles, determination, and character of a trail blazer in her chosen field. A story to develop appreciations and attitudes as well as to impart facts. (Advanced)

From Cell to Test Tube: The Science of Biochemistry by Robert Warner Chambers and Alma Smith Payne, Scribner's, 1960. An introduction to a comparatively new branch of science. Describes the trail of research which produces great discoveries. Written in fairly simple language with clear definitions of necessary scientific terms. Includes descriptions of some of the important experiments which established certain biochemical concepts. Average readers may find this book a useful reference for work on selected topics. (Advanced)

°*Master Surgeon: A Biography of Joseph Lister* by Laurence Farmer, Harper & Row, 1962. The interesting story of the man who developed the concept of antiseptic surgery. Includes interesting details of his Quaker family background, his education, and marriage. (Advanced)

Modern Medical Discoveries, Revised Edition, by Irmengarde Eberle, Crowell, 1960. Describes how scientists work to make important medical discoveries. Includes accounts of the discovery of penicillin, recent vaccines, vitamin extracts, cortisone, and sulfa drugs. (Average)

Polio Pioneers: The Story of the Fight Against Polio by Dorothy and Philip Sterling, Doubleday, 1955. Begins with the story of the earliest case of polio on record. Shows the progress of medical research and mentions some famous persons who have been afflicted with the disease. The account is an example of the continuity of scientific research. (Advanced)

°*The Wonderful World of Medicine* by Ritchie Calder, Doubleday, 1958. Describes man's progress in his search for knowledge about himself, his health, and his efforts to prolong life. Mentions world-wide health organizations and space medicine. Contains striking illustrations. (Advanced)

► INTRODUCING THE UNIT

What have bacteria to do with rotted leaves, a square of cheese, a pickle, and a jar of vinegar? Bacteria travel all over the world. Although different bacteria have special food preferences, they like the same foods

that you do and many more. They like a warm moist environment, just the kind your cells provide. How can you prevent bacteria from coming to stay with you? What part of your body always harbors helpful bacteria?

Before beginning Section 1 of the unit, you may wish to introduce pupils to the use of the microscope, as suggested on pages T-41–43. For example: How can we see bacteria so small that thousands can gather on the head of a pin without crowding? Exhibit a microscope. How is this instrument used? If you wanted to drive a car, you would need to take some lessons so you wouldn't wreck it. A microscope is a tool which can be damaged easily, but which will tell you a lot about a world you cannot see any other way. What ought we know about a microscope to get the most from using it?

Section 1: ORGANISMS WE CANNOT SEE

Pupils investigate the invisible world of microorganisms with which they share the environment. They speculate about the great number of bacteria and find that some are beneficial and others are harmful to man, but that all bacteria depend upon other organisms and upon their environment.

Introducing the Concept

What organisms can you mention that are right here in this classroom? After initial responses ask: Did you include plants? Did you include invisible organisms, too? Do you think we can get along without them? After all, germs make us ill, don't they? Explore the following questions, listing pupils' hypotheses, before suggesting that the pupils go to the text to find answers to these questions:

What are some common kinds of tiny organisms (microorganisms)? Can these organisms be seen without a microscope? How can we protect ourselves against harmful and invisible microorganisms? How do many kinds of bacteria help us?

Developing the Concept

Bacteria gardening. Microorganisms are all about us, floating on every dust particle, lying on every surface. Could we catch some and study them? How might we do it? (We might bait a trap with food they like, food we like too.)

Set a small piece of food in open air on foil or a tray for a half-hour. Cover and put in a warm, dark place. Observe at the same time each day. After two to three days you should see numerous colonies of microorganisms. Some will look like slick, shiny round spots; these are bacteria colonies. Some will look like mounds of threads; these are molds—middle-sized organisms belonging to the fungus group of nongreen plants.

(Text pages 100–03)

SUBCONCEPT

Bacteria, plants without chlorophyll, depend on other organisms for their food.

Processes emphasized

Observation

Hypothesizing

Investigation

Designing an investigation (with control experiment)

From investigation, pupils infer that heat and absence of light in the environment are essential for growth of most bacteria.

Equipment and Materials

... piece of banana, apple or orange, or other foods
... aluminum foil or a tray
... plastic or glass jar covers

Equipment and Materials

See text page 101 and consult the Teacher's Manual for *Classroom Laboratory 6*.

Bacteria can be classified, or grouped, by their structure.

Equipment and Materials

- ... match sticks
- ... radish seeds
- ... beads
- ... macaroni and spaghetti
- ... coiled springs

Bacteria can be classified as helpful or harmful to man.

Pupils apply their understanding of the needs of bacteria to methods of food preservation.

Encourage pupils to set up a design for the investigation, page 101. For this and other similar investigations, Petri dishes made of plastic are useful, for they can be sterilized easily or disposed of safely. If you do not have such dishes, they may be obtained through hospital or biology suppliers or some drugstores. When the investigation has been completed, be sure all Petri dishes and bacterial cultures are turned over to you for disposal (see pages T-42-43).

As pupils proceed with the investigation and note bacterial growth, ask: What are bacterial *colonies*? (A colony is a group of many thousands of microorganisms of the same kind living closely together.) Why do we study colonies rather than a single bacterium? (A single bacterium is invisible to the unaided eye, and visible only with a good, high-power microscope.)

What did the bacteria colonies need for growth? (Food, a place to live, warmth.) Refrigeration, you found, slows most bacterial growth. Most bacteria grow best in a warm, dark place.

Bacteria in three shapes. In earlier work in science you may have grouped rocks in three different ways. Bacteria also came in three "styles." Explanation of the Latin or Greek origin, from which the names derive, may be helpful. *Bacillus* means *little sticks*. *Spirillum* is Latin for *coil*. *Coccus* is Greek for *berry*. You may wish to think of the three kinds as hyphens, commas, and periods. You may enjoy making a design or looking for objects to represent models of each kind. Some suggested materials are listed in the margin. Encourage originality by asking for other suggestions from the pupils. If you have a microscope or microprojector, viewing of slides borrowed from the high school biology department will fascinate the pupils.

Sharing the world with microorganisms. We share the environment with about 1,600 identified kinds of bacteria. As the pupils read the text, page 102, you will want to call attention to the sentence: "Not only do most bacteria not cause disease, some are even useful." Since Section 2 will be concerned with unwelcome, or harmful, organisms, you may wish to encourage pupils to indicate some of the ways in which bacteria are useful—as in the making of buttermilk from milk or of linen from flax and in the decay of dead plants and animals, resulting in humus in the soil. Encourage pupils to look in the books on your science reading table and suggest other ways in which bacteria are helpful. The chalkboard might be used for compiling such a list.

Temperature and bacterial growth. What is the effect of heating or cooling on the growth of bacteria? When you grew bacteria (investigation, page 101), you found that cold (refrigeration) slowed bacterial growth. Most bacteria seem to grow best in a warm, dark place. What does this suggest about keeping food? (Place it in a refrigerator.) Refrigeration slows bacterial growth and prevents food "spoilage."

How does sunlight slow bacterial growth? The American Indians used one method for centuries. Do you know what it was? (They exposed

meat and other foods to smoky fires and to sunshine.) What concept were they using? (Bacteria need moisture for growth; drying removed a condition in the environment.) How many dried foods can you name from your mother's kitchen?

Although bacteria do not like sunlight, most kinds like warmth. They grow well at room temperature and especially inside your body. Do you know what your body temperature is? Why would bacteria thrive in the body if they were not in some way kept under control? (Food, moisture, darkness, no heating or cooling to speak of.)

Extending the Concept

Making bacterial slides and smears. Imbed the blunt end of a long needle in a cork or piece of Styrofoam. Using Sterno or an alcohol lamp, heat the pointed end of the metal needle to kill bacteria—or use a match flame. Dip the sterilized end into buttermilk, and spread the drop of buttermilk in the center of a glass slide. Holding the slide with forceps, pass the bottom of the slide through a flame until the glass is hot to the touch. Heat congeals the protein in the organisms and makes it stick to the slide, just as heat makes egg stick to a fry pan. Staining with a solution of household iodine, or other laboratory stain, will then wash off only nonprotein cell material. For ingredients and proportions to make prepared stains that are useful, see pages 320–21 of *The Sourcebook for the Biological Sciences*.

Pure culturing. For years the question of how to separate one kind of microorganism from another kept scientists from learning very much about bacteria. Robert Koch, a country doctor in Germany, accidentally hit on the way to do this. He reasoned that he might pick up microorganisms from one colony and grow them on a sterile piece of food. Using a solid food, such as a potato, he was able to grow a colony of just one kind of bacterium.

Try this pure culture method for yourself. Use a toothpick to lift some bacteria from one of your bacteria colonies onto slices of raw potato. Keep the slices covered. After several days observe the bacterial colonies which have grown on the potato. Because it is difficult to sterilize toothpicks and potatoes, you may get contamination from other bacteria. For sterile techniques of handling bacteria, see pages 383–85 of *The Sourcebook for the Biological Sciences*. Also see pages T-42–43.

Microorganisms and pickle making. Have you ever wondered how pickles are made? You can watch how bacteria change cucumbers into pickles. Add $\frac{1}{4}$ cupful of salt to a quart jar of water and let it dissolve. Into another clean jar put 1 tablespoonful of pickle spices, mixed with dill. Add $\frac{1}{2}$ dozen garlic cloves and some small fresh cucumbers. Fill this jar to the top with salt water from the first jar. Cover and set in a cool place. Changes begin in 24 hours. In two weeks you should have a jar of pickles. The strong salt solution draws the natural sugars out of the

Equipment and Materials

- ... needle
- ... cork or Styrofoam
- ... Sterno or alcohol lamp
- ... buttermilk
- ... glass slide
- ... kitchen forceps

Equipment and Materials

- ... a raw potato
- ... toothpick

Equipment and Materials

- ... salt
- ... two 1-quart jars
- ... mixed pickling spices
- ... dill
- ... small fresh cucumbers
- ... garlic cloves
- ... blue litmus paper

Equipment and Materials

... several grapes
... pot of soil

Equipment and Materials

... models, diagrams, or pictures
of disease-causing bacteria

Equipment and Materials

... sterile culture plates

cucumbers. Those bacteria that can survive in the environment of the salt preservative start to grow and change the sugars into lactic acid, the same acid that forms when bacilli change milk sugar to lactic acid. As the solution around the cucumbers turns acid, the cucumbers' bright green begins to pale. Lactic acid that seeps into the cucumber replaces air which is inside the cucumber. Then the pickles sink to the bottom of the jar. They will keep as long as the acid content of the pickle juice stays the same. What two chemical tests could be made to prove that pickle juice is acid? (Tasting and litmus paper. The change of blue litmus paper to pink is one chemical test for an acid reaction.)

Invisible waste disposal. How would the earth look if nothing ever decayed? Imagine the piles of trees, leaves, and dead bodies. Disposal of garbage would be quite a problem, wouldn't it? You don't have this problem, thanks to decay bacteria. Dig around a pile of rotting leaves under shrubs or trees. You should be able to see the work of yeasts, molds, and bacteria.

How do microorganisms put the important elements of organic compounds back into "circulation"? Bury some grapes in a flower pot. Water the soil and set on the window sill. After a few weeks, dig up the topsoil and you will see that the grapes have decayed and, except for their seeds, can no longer be seen. Microorganisms have reduced the grape sugars and proteins to carbon dioxide, water, and ammonia—simple substances which plants can use for growth and the building of new cells.

Which bacteria cause which diseases? One of the important concepts or discoveries leading to disease control was that of connecting specific bacteria to specific disease symptoms. A few spirilla cause disease, but the bacilli that cause tuberculosis, typhoid, diphtheria, and tetanus are among the more unwelcome bacterial visitors.

The growth of tetanus bacteria produces a substance twenty times more deadly than cobra venom. Find out from school or family medical advisers how you can be protected from tetanus, which comes from soils infected with this bacterium. Your family druggist or a medical laboratory worker may be able to show you photographs or slides of bacteria that appear in laboratory tests of patients with pneumonia or strep throat infections.

Bacteria counts. Doctors and hospitals make bacteria counts to determine prevention and treatment of infection. How are bacteria counts made? You can figure it out yourself. Each bacterium alighting on a sterile culture plate divides and multiplies so rapidly that in a day or two there is a visible colony. By counting the colonies on some of your sterile cultures, you know how many bacteria alit while the culture was uncovered. You may wish to extend the investigation by finding out if the bacteria count is the same for your classroom as for the playground. How do you explain any differences which occur? From the number of colonies, a bacteriologist can estimate the number of bacteria in a cubic yard of air wherever a sample is collected.

Reviewing the Concept

Before You Go On. 1. b 2. a 3. a 4. a

Using What You Know. 1. Bacteria and molds need warmth to grow. 2. In the refrigerator, for the same reason. 3. They aid in the decay of dead matter from plant and animal organisms, thus returning substances to the soil and air. 4. No. Most bacteria are helpful in decay, in processing types of food, clothing, etc. 5. Invisible bacteria divide rapidly, forming colonies; the colonial mass of bacteria is visible. 6. Bacteria cannot make food; they must obtain it from other organisms.

Section 2: UNWELCOME ORGANISMS

The pupils investigate the structure of a mold and gain understanding of how nongreen plants (bacteria and fungi) get their food. They also investigate conditions favorable to growth, giving them an insight into how harmful bacteria may cause infection and disease.

Introducing the Concept

Bacteria are single-celled plants. What is missing in them that is found in other plants? (Chlorophyll.) Can a plant without this substance make its own food? How do bacteria feed on the cells in an open cut or wound? What do you mean when you say that a wound has become infected? How does infection take place?

Do you think we can find out how nongreen plants get their food? Recall that bacteria are so small that about 7,500 cocci would just span 1 inch. Can you think of a common nongreen plant you can see without a microscope?

Provide a piece of moldy citrus and a piece of fresh citrus fruit. First, wash the fruit. Next, sterilize one end of a needle with a match flame or alcohol. Pierce the moldy spot of the infected fruit. Then, using the needle thus contaminated, pierce or scratch the skin of the unblemished fruit. Place this fruit in a plastic bag so that air does not reach it, and set it in a damp, dark, and warm place. Check the fruit daily. Does mold from the moldy citrus infect the unblemished fruit at the spot you pierced?

Several questions might now be used to introduce the lesson.

How do bacteria get into your body? How do nongreen plants get their food?

Developing the Concept

Structure of nongreen plants. What cell structure do bacteria have that enable us to classify them as plants? As children read text page 104, they find that bacteria possess a cell membrane plus a thickened cell wall. What inference can you make about all plants without chlorophyll? (They depend on other organisms for food.) From your reading and your observations, what likenesses and what differences can you list for molds and bacteria?

(Text page 103)

(Text pages 104-09)

SUBCONCEPT

Nongreen plants are interdependent with other organisms for their food and with their environment for conditions favorable to survival.

Processes emphasized

Observation

Investigation (with control experiment)

Hypothesizing

Theorizing

Equipment and Materials

... moldy citrus fruit

... fresh citrus fruit

... a needle

... a match or alcohol

Bacteria and molds are classified as plants by their structure.

Nongreen plants grow and reproduce rapidly in a favorable environment.

Equipment and Materials

See text page 105; also the Teacher's Manual for *Classroom Laboratory 6*.

Equipment and Materials

- ... aluminum foil trays
- ... soil
- ... samples of wood, cloth, foods, and plastics
- ... microscope

Bacteria and molds chemically break down complex foods into simple substances that can pass through a membrane.

Equipment and Materials

- ... iodine
- ... Benedict's solution
- ... soda crackers

(Consult the Teacher's Manual for *Classroom Laboratory 6*.)

Do molds and bacteria like the same kind of environment? As the pupils perform the investigation on page 105, encourage careful observation of the conditions which are best for the growth of mold. They should make a careful record of their observations—such as temperature and size of the mold growth. What one condition was favorable to the growth of the molds? (Moisture.) How do we know? (The conditions in both jars were the same, except for ten drops of water.) The investigation may be extended by using temperature and light as the other controls. Encourage pupils to design their investigations. They will find that most fungus plants (including bacteria), in addition to food, need moisture and a dark, temperate environment.

Growing molds. Although molds prefer a humid environment, they grow almost anywhere there is an invisible film of moisture. Collect some shallow aluminum trays and in each place a layer of soil. Sprinkle the soil with water and place on it various samples of materials, as suggested in the margin. Cover each container with plastic food wrap and wait for molds to grow. Do molds seem to prefer living or nonliving materials? Does color of the material make a difference in growth? You may wish to chart your results on the chalkboard.

By examining bread mold under the microscope, pupils will see what looks like a mass of white cobweb. These threadlike structures are the part of the mold plant through which it gets its food. Molds come from spores, not from seeds. You will want to be sure that pupils find the green or black ball-like body at the end of each thread. These bodies mean the mold plant is forming spores or reproducing. A spore is a single cell encased in a tough wall that protects it until it falls on a surface having conditions favorable for the growth of a new plant. Mold spores float about in the air all around you. Compare this method of reproduction from spores with that of a bacterium (text page 108).

Digestion in nongreen plants. How does food get into your cells? You may wish to review with pupils the process of digestion, whereby food taken into the body is reduced through chemical changes to simple substances that, in solution, can diffuse through cell membranes. Digestion is investigated fully in *Concepts in Science 5*. The pupils should recall that chewing of food merely breaks it into smaller pieces so that digestion can begin by the chemical action of an enzyme in saliva.

How do molds and bacteria get their food? (Both use chemical means to change complex food substances into simpler ones.) What inferences can you draw of the importance of moisture to molds and bacteria? (Food substances must be in solution to pass through a membrane; molds and bacteria digest their food *outside* their bodies.) Refer children to text pages 107–08 to find out how molds and bacteria digest food substances.

To get an idea of chemical breakdown of foods, chew a plain soda cracker. The sweetish taste you begin to notice results from a chemical change. An enzyme in saliva changes the cracker starch into simple sugars. To verify the starch content of crackers, place a drop of iodine on the

cracker. If the iodine changes from brown to bluish-black, starch is present. A drop of Benedict's solution added to a sample of saliva and chewed cracker should indicate sugar by turning reddish. The pupils may now plan the investigation on text page 106.

Food for bacteria. Do you digest everything you eat? No organism completely assimilates all it eats. Undigested and reconverted wastes go back into the soil to be reduced once again into the basic building blocks of carbon, hydrogen, oxygen, nitrogen, and a few minerals. Why must organic wastes, garbage for example, be placed in a covered container? Until reduction or decay is completed, organic wastes must be carefully handled to avoid contamination and possible infection by harmful microorganisms in them or in the products of their chemical action. Certain types of bacteria and molds give off wastes which can be very toxic to human cells. The bad smell of decaying food is evidence of bacterial action. The more bacteria, the more bacterial wastes. Why do you use an antiseptic if you cut or scratch yourself?

Extending the Concept

Plants without seeds. A fungus plant can grow and produce spores. Study the spores from between the gills of common mushrooms obtainable from a grocery store or supermarket. To make a mushroom spore print, break off a fresh mushroom cap and place it, gills down, on white or black paper. Cover the mushroom cap with a glass dish. After 24 to 48 hours, remove the glass dish and take up the cap carefully. You will see a radial design formed by spores which have fallen from the mushroom gills. The design may be "fixed" to the plate by using hair spray.

Read about and collect samples of other simple plants which reproduce by spores rather than seeds. Some are nongreen, as bacteria and molds which you have already investigated. Others are green, such as algae, lichens, liverworts, mosses (especially hair-cap moss or pigeon wheat), and ferns. For further suggestions on growing and studying these plants, see Chapter 20 in *The Sourcebook for the Biological Sciences*.

Mushroom farming. The produce manager at your grocery store or supermarket should be able to tell you if there is a mushroom farm within a day's visit. Or, if you can find mushrooms in your yard or in the woods, look for the rotted material which the mushrooms digest for food. Dig around a rotted stump or log to uncover the *mycelium*, the network of pale threads (*hyphae*) which are the lifeline between the mushroom's food supply and the spore-bearing body. Mushrooms grown for the market are a treat for some food connoisseurs. Some wild mushrooms, however, are very poisonous. Since children are not trained to identify safe mushrooms accurately, caution them not to handle any wild mushrooms with their hands—and of course no wild mushroom should be eaten unless accurately identified by an expert.

Bacteria obtain food from changing complex substances into simpler ones. The growth of large numbers of bacteria or the toxicity of substances formed may be dangerous to health.

Equipment and Materials

- ... mushroom caps
- ... glass or plastic dish cover

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. b 4. a 5. a

Using What You Know. 1. Bacteria secrete enzymes that digest the cellulose of the dead tree, breaking it down chemically into simpler food products that bacteria cells can absorb and use for growth. 2. By fission. 3. They may reproduce and destroy the cells around the wound by secreting enzymes that digest, and thereby kill, the cells. The body reacts; we say the wound is infected.

Section 3: YOUR BODY'S DEFENSE

Children investigate the defensive role against bacteria that is played by covering cells on the outer and inner surfaces of the body and by the white blood cells in the blood. They are made more aware of the importance of maintaining the tissues in healthy condition.

Introducing the Concept

Let us examine a bicycle tire and its inner tube. You may be able to borrow one from a bicycle shop. What does the outer covering do? What does the inner lining do? Both the outer covering and the inner lining have different functions, but are made of the same materials. Can you suggest a way that your body is like a bicycle tire? Does it have a protective outer covering? Recall that before food gets to your cells it has to be digested in your digestive tube. Does the lining of this tube have a protective covering through its entire length? Of what are the coverings made? (Cells—skin or covering cells, lining cells.)

Of course, here the comparison stops because the body cells are alive. What kind of environment do living cells need? (Warmth, moisture.)

What can you infer about the outside and inside covering cells? How do they protect the body? How do they make the environment chemically unfavorable for the growth of bacteria? What happens if microorganisms get through the covering cells? How can we aid in keeping body cells healthy?

Allow latitude for raising questions and making intelligent guesses, followed up, as you develop the concept, by reading and investigation as the pupils search for answers.

Developing the Concept

The skin, a first line of defense. If your pupils have not looked at cheek lining cells under a microscope, this is a good opportunity to let them see how the flat epithelial (covering) cells fit together to make a flexible covering. A volunteer, or several if you have more than one microscope, may prepare a slide by gently scraping the inside of the cheek with the tip of a toothpick and transferring the specimen to the slide. It will be more

(Text pages 110–17)

SUBCONCEPT

Organisms are structurally adapted for defense against hostile microorganisms in their environment.

Processes emphasized

Observation
Investigation
Hypothesizing
Measurement
Reporting of data
Consulting

Equipment and Materials

... bicycle tire and inner tube

Pupils investigate the protective functions of the epithelial cells that cover outer body surfaces.

visible if stained. To compare outer covering cells with the cheek lining cells, a slide may be similarly prepared from skin peelings. How are the cells alike?

Does your skin feel moist? Recall that bacteria and molds grow well on a moist surface. Do you think bacteria and other small particles, such as dust, will stick better to a dry surface than to a wet one? Set a box of dry, fine soil in front of a table fan. Direct it across the soil against a wet plate and a dry one. Which catches more particles?

What inference can you draw as to the scientific reason for daily bathing? Why do doctors and dentists wash their hands between each appointment? Why should you wash your hands before each meal? You may wish to relate health practices to the concepts of habit formation developed in Unit One.

Cell secretions—made inside, used outside. The epithelial cells inside your mouth are moistened with saliva. Name two important functions of saliva. (Moistens food, secretes enzyme that aids in changing starch to sugar.) What parts of your inner skin surfaces are moistened with mucus? (All.) What does the term *secretion* mean? Can you name secretions other than mucus? (Digestive juices, enzymes.) Remembering what you learned about reflexes and habits (Unit One), is secretion a learned or unlearned response to stimuli? Can you think of any causes for involuntary secretions—as, for example, mucus—to increase? (Irritation of dust and pollen, catching cold.)

Please cover your mouth. What role do you think mucus plays in helping to protect us? (It catches bacteria and dust irritants.) Why should you form the habit of covering your mouth and nose when you cough or sneeze? The results of unprotected coughing and sneezing (reflexes) can be shown by preparing a culture plate (see page 101). Cough or sneeze directly above a sterile plate. As a control, repeat, but this time cough or sneeze through a tissue. Cover the culture plates and observe carefully after 48 hours or so. What kind of growth begins to appear on the plates? (Bacteria colonies.) Which will show the more colonies? Can you now explain the reasons for blocking a cough or sneeze? (NOTE. Sterilize or dispose of the culture plates according to directions on pages T-42-43). Encourage the drawing of cartoons showing the importance of shielding the nose and mouth to avoid spreading bacterial infection to others.

Pupils may wish to dramatize the way cilia in the windpipe fan off unwelcome irritants and microorganisms. For example, how does their upward beating resemble rowing an anchored boat? (The oars push against the water much as cilia push the “unwelcome visitors” away so that a cough may expel them.)

Your body's chemical defenses. You have inferred from reading and investigating that bacteria need warmth and moisture for best growth and reproduction, and that mucus and cilia keep many of them from invading the body. Nevertheless, you swallow many bacteria. Why don't you, then, get sick more often?

Equipment and Materials

- ... microscope
- ... slides and cover slips
- ... stain (iodine)
- ... fine soil
- ... two plates
- ... small table fan

Pupils investigate the function of epithelial cells that line the body cavities.

The body, by reflex acts, expels bacteria and other irritants.

Equipment and Materials

- ... 2 culture plates
- ... paper tissue

Certain cells secrete substances that provide an environment unfavorable to bacteria.

Equipment and Materials

See text page 112; also the Teacher's Manual for *Classroom Laboratory 6*.

(Optional)

- ... vinegar
- ... lemon juice
- ... litmus paper
- ... test tubes or small jars
- ... meat cubes

The white blood cells are one of the body's defenses against infection.

Children find that most germs do not grow when an antiseptic is used.

Recall, if you did the investigation on pickling (page T-47), that bacterial growth can be stopped by chemical action. Antiseptics on a cut will kill bacteria (text page 111). Where in your body do you think conditions are unfavorable for the growth of bacteria? (HINT: Did you ever have an acid stomach?) Encourage children to plan the investigation on text page 112. Since strong hydrochloric acid cannot be recommended to elementary classes, you should prepare a weak solution in advance—or you may wish only to demonstrate the investigation, having students in groups follow it up as follows:

Cut four thumbnail size cubes of meat. Set each one in a clean test tube or baby food jar. Cover two cubes with water for the controls. Cover one with vinegar and another cube of meat with lemon juice. First, however, test both vinegar and lemon juice with litmus paper. Does blue litmus paper turn pink? What does this test show? (Acid properties.) Which meat spoils most rapidly? most slowly? Why? (The weak acid stops the growth of bacterial invaders and destroys many of them; the meat in water should spoil first.) Can you explain why certain secretions are chemical guards against infection? (Gastric juices, for example, contain acid.) Actually, even saliva retards the growth of certain kinds of microorganisms.

White blood cells—your body's second line of defense. What do you do if a skin cut or scrape furnishes an opening for infectious microorganisms to get into your body? Your first aid is soap and water.

As children read "Getting Rid of Bacteria," have them explain what is meant by infection. What does an infected area look like? Would you expect microorganisms to be present? What gives a pimple or boil its whitish color? (White blood cells that have moved in to destroy bacteria in the infection.) Direct the pupils to the pictures on page 113. How do white blood cells move? A comparison of the movement of the white cells as they engulf the invading *Staphylococcus* may be made with that of the "false" feet (pseudopodia) of an ameba. Some of your pupils will recall studying protozoans in earlier work in science and can describe how they move. Which is larger, an ameba or a white blood cell? (Ameba.) You may be able to obtain slides of blood counts, with the aid of the school physician, to show a few white blood cells. Although white blood cells are very small, their importance lies in the number there are in a drop of blood. Each drop of the blood of a healthy person contains from 5,000 to 7,000 white cells. Imagine the number of white cells there must be in 11 pints of blood, the average amount in a grown person. Your body's second line of defense is small only in the size of each protective cell in your blood.

Stopping growth of bacteria. Your body defenses keep bacteria under control. What can you do to help your cells? Encourage pupils to plan and set up the investigation on page 115. Let them suggest different kinds of antiseptics to be tested. Which antiseptics are commonly found on your home medicine shelf? Which are used in your school? Are all equally

effective? The investigation yields results only for microorganisms that may be found in the air of the classroom at the time the investigation is performed. Pupils may wish to chart the effect of various antiseptics, as evidenced by the growth of colonies on their culture dishes. What can you conclude about antiseptics and their action in altering the environment for bacteria? You will probably wish to caution the pupils that the result of the investigation is a generalization and not specific for specific microorganisms. Any infection should always be referred to a competent physician.

Extending the Concept

Antiseptics. Make a collection of bottles or labels of common antiseptics. Compare the contents on the labels of the containers. What seems to be the purpose of their use, judging from the containers? How many of the antiseptics contain one or more of the same chemical substances?

If possible, arrange to have the school nurse visit the class and explain modern practices in antiseptics.

Puncture wounds, burns, and insect bites. Why are puncture wounds generally considered more dangerous than cuts that bleed freely? Why is it poor practice to break open a blister resulting from a burn? How does an insect bite sometimes lead to an infection? (The small puncture from an insect bite may become infected by microbes on the skin, or they may be introduced by certain insects that are carriers of disease.)

A committee of interested pupils may consult local health authorities for information on insect carriers of germs, and control measures that they are taking. The committee may prepare a report accompanied by findings.

Don't squeeze. Acne is common among children during their teens. If evidence of the malady seems to be appearing in the class, encourage discussion of proper skin care. Why is it dangerous to "pop a pimple"? Why is infection likely to occur? What habits should be formed? Relate the concepts of habit formation in Unit One with avoidance of bacterial infection.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. a 4. b 5. b 6. b

Using What You Know. 1. Washing removes bacteria and substances favorable to their growth. 2. This treatment removes bacteria from the bruised area that may have a cut or scratch through which bacteria can enter the body. 3. It contains a "sticky" substance. 4. Decay bacteria break down substances in dead matter and return them to the environment where they can be used again; other bacteria are useful in industrial processes, as well as in producing substances useful for medical purposes. 5. Both are colorless plants and obtain their food from other living or once-living organisms. Bacteria are single-celled; molds are generally many-celled. Bacteria reproduce by cell division (fission); molds reproduce by forming spores.

Equipment and Materials

See text page 115; also the Teacher's Manual for *Classroom Laboratory 6*.

(Text pages 116-17)

(Text pages 117-23)

SUBCONCEPT

Microorganisms interact with other living things and their environment. Man changes the environment of microorganisms as he seeks to conquer disease.

Processes emphasized

Observation

Investigation (with design of experiment)

Hypothesizing

Theorizing

Analysis of scientist's processes

Designing an experiment (with controls)

Pupils recognize that the habit of seeking relationships between concepts can lead to new discoveries.

A concept is arrived at only after careful and extensive investigations and experiments.

Section 4: MOLDS TO THE RESCUE

Through analysis of the methods used by Dr. Alexander Fleming in his discovery of penicillin, pupils gain further appreciation of the relationship of living things to their environment. They discover how understanding of the concept aids scientists in altering the environment of living things as a means of combatting microorganisms that cause disease.

Introducing the Concept

In Section 2, page T-49 under "Introducing the Concept," it was suggested that molds be grown on pieces of citrus fruit placed in closed containers. Display a piece of this moldy fruit. The grayish mass with greenish spores is probably a kind of *Penicillium* mold. What does the name of the mold remind you of? Have we always had penicillin? (No. It was discovered in 1928, but was not developed extensively for use against infections until World War II.)

How do you think a scientist discovered penicillin? What steps did he follow in his work? What is an antibiotic? Are other kinds of molds sources of antibiotics?

Pupils should now read the section. Encourage them, as they read, to note especially the steps that led to the discovery of penicillin.

Developing the Concept

A mind prepared. Place on the chalkboard the famous quotation from Pasteur, "Chance favors the mind prepared." When Dr. Fleming was trying to grow a pure culture of a bacterium, what did he know about contamination that you already know? (Dust and microorganisms float in the air.) When Dr. Fleming grew cultures and when you grew bacteria colonies in Section 1, what did he and you do? (Kept the culture dish covered.) What would you have done if you had found mold growing in a culture of bacteria? Would you have considered the investigation ruined and thrown it away, as you would moldy bread or a moldy orange? Can you suggest a habit Dr. Fleming had formed as a scientist that kept him from doing this? (Careful observation.) Discuss the relationship between habit formation and the Pasteur quotation. For example, how often have you put two ideas together to see "in a flash" the answer to a bothersome question or to see a new question to investigate? What idea came to Dr. Fleming because his mind was prepared through 20 years of studying infectious microorganisms? (Perhaps some plants secrete substances that might be used against bacteria.)

Steps to discovery. Since the laboratory experiment is one tool used by the human brain in learning, it is important that pupils recognize the logical sequence of steps that lead to discovery of a concept. Ask if they can set up an experiment without an idea of what they want to find out. (No.) How did Fleming get his idea? After brief discussion, you may wish to write on the chalkboard, in scrambled order, the following head-

ings, asking the pupils to arrange them properly—in the order given below. With each heading are suggested questions that may help you guide the pupils toward understanding.

1. *Question*. What question did Fleming ask? (Does *penicillium* produce a substance that destroys bacteria?)

2. *Hypothesis* (or working idea). What was Fleming's hypothesis? (*Penicillium* may produce a substance that kills bacteria.)

3. *Design for experiment*. Why did Fleming select *Penicillium*? (Easy to grow; he had observed it had affected bacterial cultures.) On the basis of your study of molds and bacteria, what kinds of controls must Fleming have had to provide? (Pure cultures, even heat, light, darkness, moisture, culture media—and, of course, others.)

4. *Conclusions*. When did Fleming reach his conclusions? (Only after checking and rechecking his work many times.) What was Fleming's conclusion? Did it satisfy his hypothesis?

In the investigation into diastase (text page 106) you were asked to make a plan for investigating its effect on starch and to compare your design with Dr. Fleming's design for his experiment. Did you list the same steps? Did you set up controls? Did you prove that diastase helps to change starch to sugar? Pupils should answer "no" to the last two questions. You may wish to encourage discussion of other controls in their investigation, as well as the necessity for basing tentative conclusions on careful repetition of the investigation under identical conditions.

The important breakthrough. For years bacteriologists had been baffled by the problem of how to destroy disease-causing microorganisms within the body. Antiseptics that killed bacteria on the external body surfaces were injurious to sensitive internal tissues or toxic to the organism. Why was Fleming's discovery that a mold secreted a substance that killed bacteria on culture plates exciting? There are over 25,000 identified species of molds and fungi, and the air is likely to have many kinds of spores in it that fall on the food we eat. Yet they don't make us sick. Did Fleming's discovery "prove" that penicillin would kill bacteria *safely in the body*? What remained to be done? (Testing of animals and then human beings.) Why was his discovery a major breakthrough in the conquest of disease? (It suggested a new approach.) Clarify through discussion the difference between antiseptics and antibiotics.

Design an experiment. You grew bacteria colonies in Section 1 and molds in Section 2. Do you think any of the molds you grew may produce an antibiotic effective against any of the bacteria? How would you find out? Design an investigation showing your problem, your hypothesis, your plan—including controls, and a statement of results you hope to achieve. (The pupils' design should include transfer of a bit of bacterial culture from *one* colony and a bit of mold from mold growth into *fresh* culture plates.) Interested children may carry out their design under your supervision. As with all work with bacteria, you should make certain that sterile procedures are followed and proper disposal rigidly imposed.

Antibiotics change the environment of certain types of microorganisms, making it unfavorable to their survival.

Pupils gain further insight into refining their plans for investigations.

A scientist in his investigations uses the processes of learning.

Habits and experiments. Recall habit formation, which you studied in Unit One. How are the processes of learning or forming a habit like the processes of experiment by a scientist? How does a hypothesis resemble a goal? How does insight resemble a design? How is practice similar to testing? How is a scientist rewarded by his investigation? (A scientist has learned well how to learn.)

Extending the Concept

More about antibiotics. It was difficult to find a method for obtaining penicillin in quantity. Not until 1938 did Dr. Chain and Dr. Florey begin to work with penicillin and find a way to produce it in quantity. Look up and report on their work. Also read about streptomycin, chloromycetin, and aureomycin, among the many antibiotics now available. The major drug companies may have literature on antibiotics that can supplement reports.

Molds for eating and drinking. You throw away moldy fruit and moldy vegetables. But there are some foods you would not have without molds. For example, Roquefort, Camembert, and other fine cheeses owe their flavor to molds. Find out how microorganisms are used in curing and flavoring cheeses.

Molds and history. Molds spoil many foods. This fact led to the great voyages of the Age of Discovery and Exploration. A recent study shows that cinammon, cloves, and ground mustard are among the more efficient preservatives. You may test these findings yourself. Fill several baby food jars half full of beef bouillon. Add a different spice to all but one jar. Why? (The one jar is the control.) After a half-hour, cover and set in a warm place. How clear is the bouillon when held up to the light after two days? You may also add a teaspoonful of salt, sugar, or vinegar to other jars for a broader comparison. In which jars was the environment most favorable for mold growth? Chart your results and illustrate, if possible, with drawings of smears studied under a microscope. Also illustrate with maps showing where spices are grown.

From 1845-51 a potato-blight mildew (a type of mold) ruined Ireland's entire potato crop. About one million persons died of starvation and other hundreds of thousands emigrated to the United States. There were many strange guesses as to the cause of the disease. Consult the librarian for help in locating information on the cause and cure of the Irish potato disease.

Plant parasites. Molds, smuts, or rusts affect oats, wheat, corn, onions, apples, white pines, elm trees, and other plants. Investigate these plant diseases in library references. How are they controlled? Some are controlled chemically (sprays), others biotically by removing the host (barberry and currant bushes), and others by breeding resistant strains. Discuss how scientists used the concept of interaction of living things and their environment in their search for control of undesirable organisms.

Equipment and Materials

- ... baby food jars
- ... beef bouillon
- ... assorted spices
- ... salt
- ... sugar
- ... vinegar

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. a 5. a 6. b 7. a 8. a

Using What You Know. 1. No antiseptic was weak enough not to harm the sensitive cells inside the body and still kill the bacteria. 2. No. The bread was the mold's environment and supplied the moisture.

Section 5: ANOTHER BATTLE: ANOTHER VICTORY

Pupils gain further insight into the difficult conquest of diseases. Antiseptics and antibiotics are not enough. Applying the basic concept that living things require a favorable environment, bacteriologists rely on many methods of altering the internal environment of the body so that it is unsuitable to disease-causing microorganisms.

Introducing the Concept

Encourage the pupils to volunteer a listing of infections, diseases, and accidental injuries they may have had. Write them on the board without comment—even the common cold, if it is mentioned. How did you or the doctor treat them? For which were you treated with an antiseptic? With antibiotics? Do you think you can have any of these infections or diseases again? Why? What diseases are you not likely to get because you are immune to them?

After discussion, encourage pupils to read the section closely, with special attention to these questions.

Why have some diseases been so hard to conquer? What is a virus? What does being immune mean? What are antibodies and how are they produced? Why do doctors suggest vaccinations, injections, or oral vaccines for certain diseases?

Developing the Concept

What is a virus? In earlier work the pupils have probably used a filter to separate solids from liquids. Recall how small a bacterium is and explain that bacteriologists can separate bacteria from a liquid by using a fine porcelain filter. Viruses go through the filter easily. Can you see body cells under the classroom microscope? (Yes.) Can you see bacteria? (Only the very largest.) Most bacteria must be magnified 1,000 times or more to be seen. Draw a circle 6 inches in diameter on the board to represent a coccus bacterium. Next to it draw a circle $\frac{1}{2}$ inch to 1 inch in diameter to present a pox virus. Both of these represent a magnification of about 300,000 times or more. Why did bacteriologists have to wait until technologists invented an electron microscope before they could see a virus? (Light will not make visible any objects much smaller than bacteria. The concept of the structure of the atom and the behavior of electrons had to be formulated.) An electron microscope may be taller than

(Text pages 122–23)

(Text pages 124–30)

SUBCONCEPT

Viruses interact with other living things and their environment. Man changes the environment of viruses in seeking to conquer disease.

Processes emphasized

Observation
Investigation
Theorizing
Hypothesizing
Library research

The favorable environment for a virus is within the body cells.

you are. The material to be studied is placed not on a slide, but on a film only two millionths of an inch thick. Instead of light, a stream of electrons outlines and permits magnification of objects as small as viruses.

In what form of matter must a substance be to pass through a membrane? From their earlier understanding of digestion, pupils should correctly infer that only molecules pass through a membrane. Single bacteria are single cells, they cannot get through a cell membrane into body cells. Viruses are thought to be like DNA, the large protein molecule that is able to duplicate itself and that determines characteristics that are inherited. Viruses can pass through cell membranes. Inside the cells, they multiply and thus disturb the function of the cells.

Immunity. Have you had mumps or chicken pox? Are you likely to get them again? (No.) Why not? You are immune to them; but what does immunity mean? If you have been given antibiotics for a *Staphylococcus* infection, are you immune to staph infections? (No.) How do we get immunity? (From formation or introduction of antibodies.) Discussion should elicit that having had a certain disease gives natural immunity, and that vaccination or injections give acquired immunity.

Following the reasoning. The conquest of polio illustrates how scientists and technologists conquered a disease dreaded for the death or crippling effects it caused. Your text provides this evidence that was available to the scientist who attacked the problem of polio:

1. Vaccination with cowpox gives immunity to smallpox.
2. Persons surviving typhoid, mumps, or measles do not contract the disease again.
3. Injections of material from an animal with rabies kept a boy from certain death. (Pasteur's bold hypothesis and successful trial.)
4. Certain diseases are caused by viruses. (The invention of the electron microscope made possible the isolation of this specific agent causing a specific disease.)

Imagine you are a scientist, what ideas might occur to you for attacking the problem of providing a vaccine for polio? (Some of the suggested answers pupils may give are in parentheses. Of course, there are others.) How would you state the problem? (Can we develop a safe means of aiding a person to build up immunity to a disease without giving him the disease; that is, how can we safely aid his body to build up antibodies against the polio virus?) How would you state the hypothesis? (A safe vaccine can be made from the polio virus; it should cause the body cells to produce antibodies that will give immunity.) Why should you find that trying to design an experiment would be difficult? (The hypothesis raised other questions: How can we grow the virus? How can we weaken it so that it will safely produce the effect desired? How can we safely test the vaccine? How can we be sure it works?)

Encourage the pupils to cite from their text, examples of the work of Enders, Salk, and Sabin. In what ways do the Salk and Sabin vaccines differ?

Some diseases cause the body to build immunity.

By studying evidence and applying concepts, scientists have found a means of conquering many diseases.

Virus culture. Why was culturing a virus difficult? Have the pupils recall how they cultured molds and bacteria. Can you grow a virus on a nutrient jelly or on a piece of bread? Bacteria feed *on* cells. Virus can grow only *inside* cells. A hen's egg is a large living cell. Dr. Enders and others used the hen's egg to grow polio viruses. Fertilized eggs or chick embryos seem to provide the right environment, especially if kept close to body temperature (98.6° F.).

Antiseptics, antibiotics, and antibodies. Encourage the pupils to devise ways of making clear the difference between these terms. It may perhaps best be shown by a drawing or chart. Pupils should develop the idea that antiseptics and antibiotics are specific against a disease. Only antibodies give lasting immunity, but all these are part of the chemical defenses against disease.

Victories over disease. Refer the pupils to the table on text page 129. Why did winning the victory take so long? What concepts had to be discovered? What applications of them had to be made? Can we say that any one scientist alone won the victory in any of the battles for conquest of a disease? Modern medical research is a team operation. What characteristics do you think the members of the team must have? Pupils should illustrate from their understanding of concepts of learning and other processes of scientific investigation. Could a scientific team win the battle against disease without your help? (No.) In what ways can you help? (Practice good health habits, report to your doctor if you are ill, have regular physical examinations, etc.)

Extending the Concept

Dr. Jenner and smallpox. Investigate and report on the work of Dr. Edward Jenner. Without an electron microscope or even the knowledge that microorganisms caused disease, he developed a vaccine that protects you today. Be sure to include his hypothesis, his design for testing it, and the results. You may wish to compare his procedures with those of Dr. Jonas Salk in his work on polio.

Dr. Reed and yellow fever. The nationally known Walter Reed Hospital in Washington, D.C. is named after a brave Army doctor who, in Cuba during the Spanish-American War, proved that yellow fever was caused by the bite of a mosquito carrying the disease organism. Investigate his work in the library. Compare his methods with those of Dr. Salk and Dr. Sabin.

Plant viruses. With the librarian's help you may be able to read about the work of Wendell Stanley on the mosaic virus of tobacco. When he had succeeded in isolating it in crystal form, a quantity of it was like a box of salt on a shelf. Yet these crystals infected healthy plants when injected into them. Look up and report other evidence of plant virus infections, as in the cucumber or the flowering maple (*Abutilon*). Agricultural agents and nurserymen may be able to supply information and examples of plant virus infection. How are the viruses controlled?

The environment for growth of viruses differs from that of other living things.

Only antibodies give immunity.

Pupils infer that the conquest of disease is a cooperative effort.

Weakening viruses. Your text tells you that the Sabin vaccine used weakened viruses (page 128). What ways have you discovered of killing bacteria and molds or weakening their growth? (Refrigeration, drying, removing their food, chemically treating them, growing weak strains.) How can viruses be weakened? Try to obtain information on Dr. Sabin's work and prepare a report.

(Text page 130)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. a 5. a

Using What You Know. 1. Antiseptics kill bacteria outside the body; antibiotics are substances produced by molds and used inside the body to combat bacterial infections; antibodies are substances made within the body, giving it immunity against a specific disease, frequently viral. 2. Natural immunity results from having a disease, acquired immunity from a vaccine.

(Text pages 131-38)

SUBCONCEPT

Modern technology uses concepts of science to free the environment of harmful microorganisms.

Processes emphasized

Library research
Observation
Investigation
Invention of models
Designing an investigation (experiment with controls)
Hypothesizing

Section 6: HEALTH—A PUBLIC CONCERN

Pupils investigate some of the advances in technology that keep harmful bacteria and other microorganisms from contaminating food, water, and the surrounding air.

Introducing the Concept

Years ago, in 1892, an epidemic of cholera spread from India to Europe and then to America. In Germany, the port of Hamburg and the city of Altona are next to each other. Sewage was dumped into the Elbe River, but both cities obtained their drinking water from the same source. Altona filtered its water through sand, but Hamburg did not. In Hamburg over 8,500 persons died of cholera, but only 328 died in Altona. Pupils discuss possible hypotheses for this difference in death rate.

Typhoid epidemics, tuberculosis, and other diseases used to kill many persons less than 100 years ago. The disease germs were carried in water or milk. Within the last few hours you probably had a drink of water and probably also a glass of milk for breakfast. How could you be sure you would not come down with cholera or typhoid, or some other dread disease? Can you mention some methods man has invented to keep undesirable germs away from the food he eats, the water he drinks, and the air he breathes? What did he need to know before he could invent these methods? Encourage the pupils to relate science understandings with the technological invention. With some classes lively discussion may be stimulated. With others you may wish to suggest the reading of the text with attention to the following questions:

Who are responsible for protecting your food and water supply? How can microorganisms be kept out of well water? How can we make sure water in a reservoir is fit to drink in every house? Is health a personal concern? Or should it be the job of government agencies only?

Developing the Concept

How is milk pasteurized? Why is milk a favorable environment for bacteria? Recall their needs for food and moisture. Display a milk carton. What word on the carton indicates that it has been treated against harmful organisms? What does pasteurization do? Commercially, milk is pasteurized by heating it to 145° F. and holding it at this temperature for 20–30 minutes, and then cooling it rapidly. This process kills only the harmful disease bacteria; other microorganisms in the milk are kept from growing by the rapid cooling.

Pasteurization can be simulated by using higher temperature for a shorter time. Heat a half pint of raw milk in a small metal container. Bring it to 175° F. and keep it at this temperature for 15–30 seconds. Imbed the container in a bowl of ice. (The metal container will not crack as glass might under rapid cooling.)

Will pasteurized milk turn sour as fast as raw milk? Set a test tube or small bottle of raw milk and your “pasteurized” milk in a safe place for several days. Placing them inside a quart glass jar will insure safe keeping. Label each tube. What test can you use instead of taste or smell to determine if the milk sours? (Use blue litmus paper as an indicator.) Test a small sample of each tube each day at the same time. How soon does the litmus paper turn pink? What does this indicate? When the milk warms up, bacteria surviving pasteurization begin to grow. Their digestion of milk sugar, a carbohydrate, begins to break the milk down into lactic acid.

Filtration of the water supply. How does water travel from a cloud to your faucet? Streak a line on the chalkboard with a wet sponge. It soon dries. Where does the water go? Suggest that the pupils read text pages 131–32. It may be useful to recall, from earlier work in science, the evaporation-condensation cycle.

Where is the watershed for the reservoir that supplies your local water? Pupils may be encouraged to design a model of a watershed, preferably outdoors, in a shallow carton which can later be pulled apart and disassembled. Attach spouts of foil to the bottom of the carton with containers under them to catch the run-off. Mound up soil and pebbles in the runoff. Sprinkle from above with water to simulate rainfall. Is the runoff clear? (No.)

How would you purify run-off water from a watershed? A miniature filtration plant can be demonstrated by using a large funnel filled with layers of sand and gravel. (See Figure 11-2, *The Sourcebook for Elementary Science*. For use of alum in settling solids out of water, see page 186.) As the water flows through the funnel filter, does it become clear? Is the water now purified? Encourage pupils to develop their own hypotheses and then verify by investigation.

Chemical purification of the water supply. As the pupils read the text, pages 132–33, they become aware that filtration often does not remove harmful bacteria from water. In what ways can bacteria be destroyed?

Harmful bacteria in milk are destroyed by pasteurization.

Equipment and Materials

- ... carton of raw milk
- ... kitchen thermometer
- ... metal container
- ... watch with second hand
- ... hot plate
- ... dish of cracked ice cubes
- ... 2 test tubes or jars
- ... blue litmus paper
- ... quart jar

Many harmful bacteria and undesirable solids are removed from water by filtration.

Equipment and Materials

- ... shallow carton
- ... aluminum foil
- ... soil and pebbles
- ... sand and gravel
- ... sprinkling can
- ... funnel
- ... containers

Bacteria may be chemically removed from water to make it suitable for drinking.

(Boiling, freezing, use of chemicals.) Which would be effective in a large reservoir? How can you tell if the water still contains bacteria? (Grow cultures as in Section 1.) How can the water be freed of these bacteria? Recall the effectiveness of antiseptics. How do they kill bacteria? (Chemically.) In many communities, chemical substances, such as chlorine or compounds of chlorine, are added to the water to kill microorganisms. In small amounts, chlorine is not harmful to the body. Encourage pupils to carry out the "Investigation into Purifying Water with Chemicals" (text page 134), and to design additional investigations. What chemical substances, if any, are added to the water by your community?

A country water supply. In a country water supply system, water often comes directly from the ground and is led through pipes into the home. As children read the text pages 133 and 135-36, most of them will recall "digging" for water at the seashore or near a lake. If children find it difficult to understand what the water table is, you can easily clarify it by a simple investigation.

Fill an aquarium or wide-mouthed jar $\frac{3}{4}$ full of gravel near the bottom and top it with fine sand or soil. Slowly add water until a water line appears about $\frac{1}{3}$ or $\frac{1}{2}$ way up the jar. Select a volunteer to dig down carefully into the soil until he reaches water. A dug well is based on the same principle. A drill is sunk into the earth to the water, which has been naturally purified by filtering through the soil and gravel.

Porous rock filters out germs. However, the water should be tested from time to time for purity. You may wish to check with your local health department office to find out how well water is tested. Water coming from a well deep in the ground (an artesian well) is usually safe to drink. An artesian well model may be made by attaching a length of rubber or plastic tubing to a large funnel filled with sand. Pour water into the funnel while holding the end of the tubing higher than the mouth of the funnel. The farther the tube is lowered, the more strongly the water spurts out. An artesian well catches water between rock layers; a pipe sunk to the water allows an outlet for the pressure, and the water rises. Pupils should be encouraged to carry out individually the research investigation on text page 137.

Extending the Concept

Community health laws. Secure information about local health ordinances from school or public health department personnel.

Look for stamps or seals of inspection on meats and other foods in a supermarket. What do food inspectors watch for? Your cafeteria manager, or a local druggist, may help you find out what difference the Federal Pure Food and Drug Act makes to you.

Flying microbes. Since cold and flu viruses are believed to be air-borne, you know the reason for smothering coughs and sneezes.

World air travel, especially from countries with lax health laws and standards, increases the difficulty of protecting your health. Imagine, for

Equipment and Materials

- ... aquarium or large jar
- ... gravel
- ... sand or soil
- ... funnel
- ... rubber or plastic tubing

example, trying to find cholera viruses in the clothes and baggage and on the skin of a person returning from the Orient. If you live near a border immigration station or near an airport with a customs section, you may be able to find out about the regulations for health inspection for incoming travelers.

Persons who handle food. Restaurant workers must handle food daily. Requirements for hand washing, use of hair nets, periodic chest X rays, and other forms of cleanliness are established by the Board of Health. Restaurants are periodically checked to see if certain standards are being maintained. Investigate and report on local health regulations for the restaurants in your community. The school cafeteria manager may also be able to tell you about health practices in the preparation of school lunches.

On culture plates, you can grow bacteria from the hands and hair. This may be done by preparing plates as you have done earlier in this unit. Select two volunteers, one to place his hand print on a culture plate, another to furnish a strand of hair which is placed on another culture plate. After 24 hours observe the plates. Can you suggest why clean hands and hair are important in maintaining good health?

Depth of wells. In different areas, the depths one must drill to secure safe drinking water may vary greatly. What type of soil and land elevation have to do with the depth of a well? Children may wish to go to the library for answers to this question.

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b

Section 7: THE MAIN CONCEPT: CONTROLLING THE ENVIRONMENT

All organisms depend on the environment for food, water, and shelter. Sometimes the competition for these basic necessities creates an environment unfriendly to other organisms—among them man. Through the ideas of science and the tools of technology, man has been able to adapt, modify, and control his environment. Microorganisms are adapted to their special environment, but man is aided by beneficial organisms and harmed by others that threaten his survival. Medical research gives man a means of controlling the environment by seeking the causes and cures of diseases caused by microorganisms.

CONCEPT SUMMARY

NOTE. As you and the pupils review together the main concept of this unit, several opportunities present themselves for adding information that can clarify the relationship between science and technology. You may wish, as you present this information and as the pupils read the section,

Equipment and Materials

... 2 culture plates

(Text page 138)

(Text pages 139–45)

CONCEPTUAL SCHEME

Living things are interdependent with one another and with the environment.

UNIT CONCEPT

Living things are adapted to structure and function to the environment.

Processes emphasized

Concept forming
Theorizing

How are you like a bacterium?

Equipment and Materials

... balloon
... bread

What microorganisms did Leeuwenhoek see through his microscope?

What does to be quarantined mean?

Why was Koch's isolation of the bacillus causing tuberculosis a turning point in bacteriological studies?

Equipment and Materials

... Jell-o
... agar

What conditions inhibit the growth of bacteria and molds?

to develop discussion, demonstrations, or pupil investigations that will deepen understanding of the concepts.

The needs of organisms. How are you like a bacterium? (Neither you nor bacteria make the food you eat.) What coloring matter do your cells lack? (Green, due to absence of chlorophyll.) Both you and most bacteria depend on green plants for oxygen. How does food get into your cells? How does it get into a bacterium which has only a single cell? An inflated balloon can serve as a model of a coccus bacteria. Imagine that the "coccus" needs to "eat" bread for energy to go and grow. How could bread get into the closed balloon; that is, how can bread get inside a cell? Pupils recall that digestion breaks down complex food substances into simpler substances that can pass through cell membranes. This digestion takes place outside the cell.

Molds and bacteria are nongreen organisms. In what ways do they behave alike? (Both are consumers of food energy stored by other organisms.)

The first bacteriologist. The first scientist to see bacteria was Anton van Leeuwenhoek, a Dutch lens maker. With his crude microscope, which magnified about 100 times, he explored a whole new world of microorganisms. He carefully recorded and pictured everything he saw. Encourage student reports and drawings of their explorations with a microscope, and post them on the class bulletin boards.

Quarantine. Persons who have contagious diseases are sometimes isolated from others by being quarantined. Which diseases are quarantined? Where did the term *quarantine* come from? The French word for *forty* (*quarante*) gives a clue. A good dictionary will furnish additional information. Children may wish to make a chart listing diseases which are subject to quarantine.

Tracing the culprits. Robert Koch, a German bacteriologist, developed a technique for pure culturing of bacteria that led to his discovery and isolation of the bacillus causing tuberculosis. His pinpointing of a specific bacterium as the cause of a specific disease shortened the search for ways to cure many other feared diseases. Dr. Koch's bacterial potato culture (Section 1, page T-47) was the key to pure culturing. Food jelly made with gelatin seemed to be better, but it offered problems. Your body temperature is ideal for bacteria growth. What happens to a drop of Jell-o on your warm skin? (As it warms, Jell-o, a gelatin, liquifies.) Thus, many gelatins, if used in bacteria culturing, would scatter and mix bacteria, preventing a pure culture. Dr. Koch learned about agar from a Dutch housewife, whose friends in Java used a seaweed agar to thicken soup. Prepared food nutrients now used in culturing bacteria include agar made from seaweed. You may wish to secure some powdered agar from a druggist to make some agar jelly. Does agar, like Jell-o, melt at body temperature? Why is agar more useful in bacteria culturing than a gelatin?

Destroying bacteria and molds. What methods did you find weakened or destroyed bacteria and molds? Drying and chilling slowed growth,

but about 10 per cent of bacteria form spores that are not easy to destroy. These single-celled bacteria, under unfavorable conditions, develop a coat that protects the spore against heat, cold, drying out, and even lack of food. Spores can stand boiling water longer than any other living thing. Steam heat, about 30° to 40° above boiling, such as your mother uses in a pressure cooker, is about the only way to kill spores. To see what boiling does to cells of plants or meats, make microscope slides of such cells before and after cooking, and view them under a microscope. What changes do you notice in the cells?

To weaken an organism without killing it, what methods might you use? (Chilling, drying, starving, infecting, or cultivating weak strains.)

How did it happen? On a hill above a ghost town in a mining region of Colorado is a cemetery. From reading the headstones, you would find that by the early age of 30 most of the inhabitants had died of typhoid. From what you have learned about water-borne diseases and the proper handling of sewage, how might their deaths have been prevented?

Spontaneous generation. One of the great ideas upon which bacteriology has been built is another contribution from Pasteur. Many persons in his day believed that microorganisms—at least many of them—suddenly appeared from nonliving matter. By testing a hypothesis that living things could only come from other living things, he proved indisputably that every microorganism must have a parent. With the help of a reference librarian, investigate and report on “spontaneous generation,” the appearance of life from nowhere.

Superstitions and science. Until the advent of modern science, people could not often understand why things happened. It was easy to believe that anything they didn't understand was caused by evil spirits. The history of medicine and of man is full of superstitions about diseases. Why do you think there were so many American Indians and other primitive peoples who turned early to nature for curatives? For example, wintergreen was used as a cure for rheumatism, and quinine bark for malaria. A pharmaceutical supply house often has interesting material on origins of sources of common drugs. If your library has a copy of *Rats, Lice and History* by Hans Zinser, you may be surprised to find how the history of entire nations has been affected by microorganisms.

Relating science and medical technology. This unit enlarges on the concept that living things are interdependent with one another and with their environment. As scientists and technologists saw more and more clearly how a longer life was related to this concept, they directed their attention to ways of controlling unfavorable living things in man's environment. To summarize how scientific discoveries and technological inventions work interdependently, you may wish to divide the class into groups, each to prepare a panel discussion on one of the questions on page T-68. Or you may wish to encourage general discussion followed by group reports. The important point is to generate thoughtful appreciation of the interacting roles of the scientist and technologist.

Why is sanitation important?

Do microorganisms come from nowhere?

What superstitions about disease are still prevalent?

How are science and technology interdependent in the conquest of disease?

1. Why was the invention of the ordinary (light) microscope important in man's search for a longer life? (It led to discovery of bacteria, knowledge of the cell structure of all organisms, and of the functions of cells in relation to their environment, etc.)

2. How did the invention and improvement of methods of bacteria culturing outside the body contribute to medical progress? (Most bacteria could be grown pure and their functions studied, resulting in modern medical practices and regulations for food handling, water purification, sewage disposal, etc.)

3. How did the knowledge of interaction of cells and microorganisms with their environment lead to the invention of antiseptics and antibiotics? (It gave insight into control of microorganisms inside and outside the body.)

4. How was the invention of the electron microscope a major technological breakthrough in man's battle against virus-caused diseases? (Viruses could be seen, cultured, and studied in relation to environmental conditions, which resulted in the invention of ways to introduce antibodies into the environment in which viruses grow, etc.)

5. How does "chance favor the mind prepared"? (How scientists and inventors hit upon hypotheses and found ways to solve their problems. Pupils cite specific work of scientists.)

(Text pages 142-45)

FIXING THE MAIN CONCEPTS

Testing Yourself. 1. a. Bacteria. b. Probably; the well is probably near farm buildings and may be contaminated from sewage. The bacteria may cause disease. c. Move the buildings or sink a new well farther away for permanent cure of condition. Filter and boil the water for present use. d. Chlorination. 2. Children inoculated against diphtheria; pure food and water regulations control typhoid infections. 3. Sets up regulations for inspecting food and water supplies so that diseases cannot be spread by means of contaminated food or water. Local governments build reservoirs, test for bacterial content, provide filtration and chlorination of water supplies. Other answers possible. 4. a. Boiling kills microorganisms that might cause diseases. b. Chilling keeps microorganisms from growing. c. Filtering removes solids and many microorganisms. d. Chlorine in small quantities kills bacteria and is harmless to human beings. 5. Antiseptics kill the soft internal body cells; antibiotics generally are harmless to body cells, but kill bacteria and other microorganisms; antibodies harmless to body cells but destroy specific viruses. 6. Consult glossary on text page 422.

Quick Test. 1. c 2. a 3. c 4. d 5. b

A CONCEPT OF INTERDEPENDENCE: A NEW VIEW

In this first new view in *Concepts in Science 6*, pupils consider the interrelationships of many concepts that support the conceptual scheme of the first three units. By briefly reviewing classification of living things, they see that living things are related by common structures with which they perform life functions. But man alone possesses a structure so well developed that he can learn and apply his learnings. Thus he understands, through concepts he develops, that all living things are interdependent with one another and with their environment, and can apply this great concept to control both the conditions in the environment and the living things in it.

TEACHING SUGGESTIONS

You already know much more than a good scientist knew two hundred years ago. How is this possible? What is the biggest book you have ever seen? Probably Webster's largest dictionary. It might take a book of this size to hold all the knowledge that is now known about penicillin, discovered as recently as 1928. You know about all kinds of animals and plants. For example, if you were to visit Mars and picked up a feather or a bit of fur, what inferences would you make? (Life would exist on Mars. But even more. There would be birds and mammals and plants—or at least some form of life that captures and stores energy—existing there; there would be enough oxygen to support life, as well as minerals and other elements that help build bones and muscles and aid in growth and repair of body tissues.) How can you make these inferences? (From concepts that we have developed.) The recent photographs from the Mariner spacecraft seem to indicate this type is unlikely. However, the inferences are still valid.

If possible, arrange to visit a woods. Each pupil should have a notebook or a few sheets of paper ruled into two columns headed PLANTS and ANIMALS. For each plant, an animal seen on or near it should be listed, as: oak tree—squirrel; shrub—sparrow (and nest); wild rose—green worm. After returning to class, discuss the number and kinds of plants and animals living together. In what ways are they alike? In what ways different? Can either live without the other? In this way, lead up to pupils' formulations of conceptual statements of hidden likenesses in structure and function (through classification), and the concepts of interdependence and adaptation to environment. The charts on text pages 147 and 148 should then be examined and discussed. If a visit to a woods is not possible, a tour of the school grounds will provide a similar opportunity to investigate the environment.

Discuss text pages 147–49. How do the plants and animals seen on the tour of the woods or school grounds fit into the pyramid of life? Another way of showing interdependence is to relate the feeding habits to a chain

(Text pages 146–51)

CONCEPT RELATIONSHIPS

In his attempts to understand the world in which he lives, man has developed the large conceptual scheme that living things are interdependent with one another and the environment. Many smaller concepts support this conceptual scheme.

Concepts are a base for drawing inferences.

Searching for hidden likenesses leads to concepts.

Living things are interdependent.

that traces back to the energy from the sun. Pupils may diagram this *food chain* relationship. Other pupils may diagram the interchange of oxygen and carbon dioxide between a green plant and an animal—a horse and grass by reference to page 150. What other kinds of interchange are there? Pupils may recall the role of decay bacteria, for example.

Technologists apply concepts.

The text, page 151, mentions hides and fibers—products we use because of technology. Review how technologists apply the concepts formulated by scientists. On what other animals or plant substances is man interdependent with other living things in his environment? A listing can be quite long and interesting. How is man dependent on his physical environment? Discuss and add other technological examples, citing the concepts used, to those on page 151.

Man attempts to manage his environment.

To start thinking about the final paragraph of the section, you may wish to relate what happened in the region around the Grand Canyon when a campaign to eliminate mountain lions that occasionally killed a few cattle was instituted. The deer population multiplied so fast that the deer literally ate themselves out of their environment. With reduction of their food supply, they died off in great numbers. Interested pupils might investigate such subjects as soil, water, forest, and wildlife conservation, relating their reports to man's application of the concept of interdependence.

TEACHER'S NOTES



UNIT THREE

IDEAS AND TOOLS: FOR LONGER LIFE

In 1870, rabies was a deadly disease. Joseph Meister had been bitten by a dog with the rabies disease. He would have died—except for Louis Pasteur.

In Pasteur's time it was not known that rabies was caused by a virus; but Louis Pasteur had the idea that germs cause disease and he pursued the idea. Moreover, he had the idea that when weakened disease germs were injected into the body, the body produced substances which destroyed the germs.

Pasteur investigated his ideas. He experimented with rabies and his injections had saved many animals from that dread disease. He had not tried his injections on human beings. Should he or shouldn't he? Faced with the possibility of saving a life, he did inject the weakened rabies virus into Joseph Meister. Joseph Meister lived.

Ever since the time of Pasteur, ideas (such as the germ theory of disease) and tools (such as microscopes and drugs) have been used to conquer disease. This unit is the study of how man uses his brain and his hands, his imagination and his skill, to change his environment and lengthen his life.



1. Organisms We Cannot See

The medicine dropper in the picture contains sour milk. ■ It contains many tiny **organisms** (ô'gən·iz'əmz). In fact, the single drop of milk about to fall from the end of the dropper may contain as many organisms as there are people in the United States.

A Microscopic View of Tiny Organisms

Organisms too small to be seen by the unaided eye are called **microorganisms** (mī'krō·ô'gən·iz'əmz). They can be seen only with a microscope. A microscope has several lenses arranged to magnify tiny plants and animals that are invisible to the naked eye. Under a microscope these organisms appear many times larger than they really are. If you look at a drop of sour milk through a microscope, you will see organisms like those shown in the picture. ●

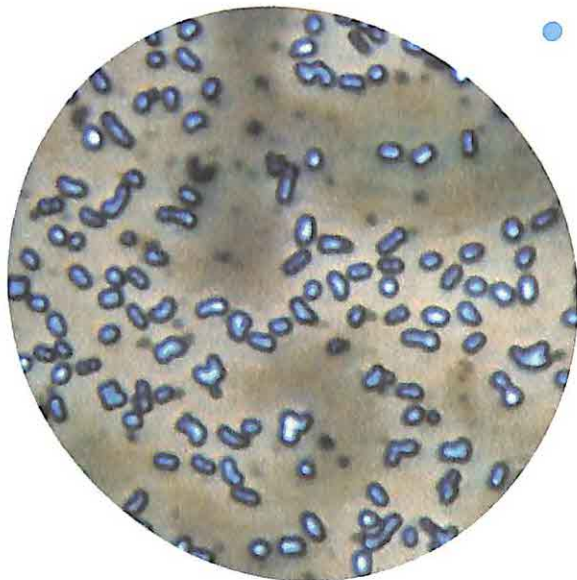


The tiny, rod-shaped organisms are **bacteria**. Bacteria are the smallest living plants. Some kinds of bacteria cause disease but most of them do not. The rod-shaped bacteria shown in the picture are not harmful. They cause milk to sour and therefore are found in sour milk and also in buttermilk. Buttermilk, in fact, is a healthful drink.

Find out more about bacteria and how they grow by doing the investigation on the opposite page.

Kinds of Bacteria

There are millions of bacteria in one colony. *Some* of them may be harmful, so for reasons of safety, you should examine a colony of bacteria only with the help of your teacher. If your school has a high-powered microscope (400× or more), your teacher may prepare slides with the bacteria from the **cultures** so that you can study them.



AN INVESTIGATION into Growing Bacteria

Needed: a microscope (400 $\times$ or more); a medicine dropper; sour milk; two Pyrex dishes; sheets of plastic and rubber bands (or glass lids for the Pyrex dishes); a package of plain gelatin; one bouillon cube

With a medicine dropper, put a drop of sour milk on a clean glass slide. If the drop is very thick, add one drop of water to the slide. Place a cover glass over the drop. Then examine the drop under the microscope. Is what you see similar to that shown in the picture on the opposite page?

A single **bacterium** is invisible to the unaided eye; but when many of them multiply and form **colonies**, you can see the colonies. Grow some colonies of bacteria; but do so *only with the help of your teacher*.

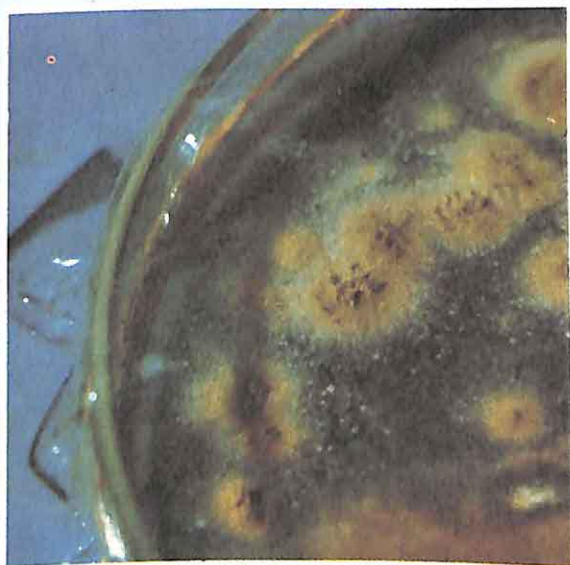
Half-fill two Pyrex dishes with a mixture made as follows:

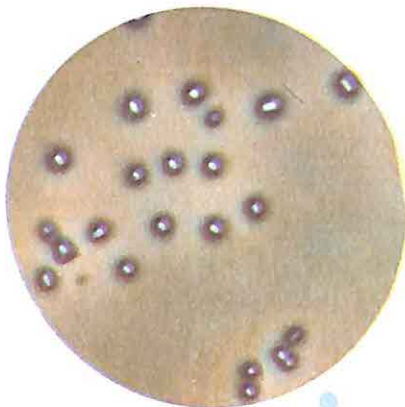
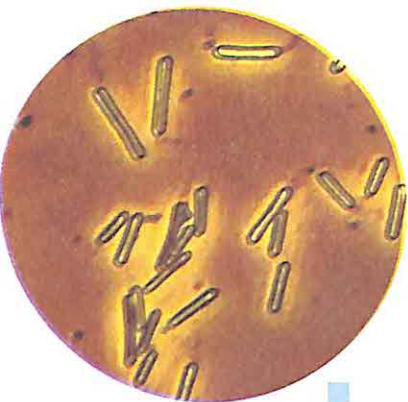
To a cup of boiling water add the contents from one package of plain gelatin and one bouillon cube. Stir until the ingredients are dissolved. Then add one-half cup cold water and stir. While the mixture is still warm, pour it into the Pyrex dishes. Leave both dishes uncovered for several hours; then put a plastic sheet over each dish and fasten it with a rubber band (or use glass lids). ■ Place one dish in a refrigerator. Leave the other in a warm, dark place.



After several days, do you find blotches, or spots, on the dish left in the warm place? These are the colonies of bacteria. Do they look like those in the picture? ● Were all the bacteria of the same shape?

Look at the dish in the refrigerator. What is the effect of cold on the growth of bacteria?





If you were to examine the bacteria under a microscope, you might find three types.

The bacteria shown first are rod-shaped bacteria called **bacilli** (bə-sil'i). ■ The spherical bacteria are called **cocci** (kok'si) ●, and a third type, shaped like a corkscrew, is called **spirillum** (spī-ril'am). ▲ Many corkscrew bacteria in colonies are **spirilla** (spī-ril'lə), plural for spirillum.

These are the three kinds of bacteria that are found all around you. Some of them may be harmful, but most of them are harmless.



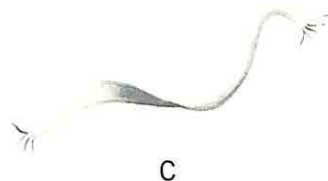
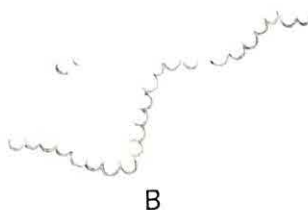
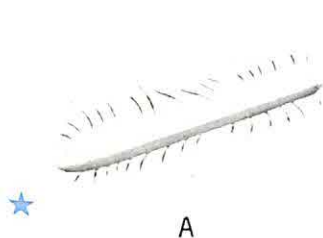
Not only do most bacteria not cause disease; some are even useful. Some kinds of bacteria are used in making linen from a plant called flax. Some kinds, called decay bacteria, break down dead animals and plants, and return the matter to the soil. Without such bacteria the world would soon be full of dead things. Imagine a forest full of dead trees, just lying there. In time, no trees could grow, for there would be no **humus** (hyōō'məs) in the soil. Decay bacteria cause dead plants and animals to break down to form humus, an important part of the soil. ● Humus restores to the soil the **minerals** that plants need in order to live and grow.

Not all bacteria, however, are beneficial to man. Some are extremely dangerous. They feed on tissues in the body and cause many serious diseases. Scientists and medical doctors are working to rid us of these unwelcome pests, and, thereby, to improve the environment in which we live. The following sections tell of this great battle that goes on between men and disease germs.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Geraniums and bacteria are alike in that they both
 - a. have leaves
 - b. are plants
2. Geraniums and bacteria are unlike in that bacteria have
 - a. no roots
 - b. roots
3. Look at the drawings of the three microscopic organisms shown below.★ They are all
 - a. bacteria
 - b. bacilli



4. Bacteria which cause decay are usually
 - a. helpful
 - b. harmful

B. Write a paragraph or two on this topic: Some Helpful Bacteria.

**USING WHAT
YOU KNOW**

1. Why is it important to put certain foods in a refrigerator?
2. Where would most vegetables (for example, lettuce) and fruits (for example, apples or oranges) keep better—in the refrigerator or outside the refrigerator?
3. Of what use are bacteria in a forest?
4. Suppose all bacteria were destroyed. Would this be good for living things?
5. How is it possible to see bacteria without a microscope?
6. Most bacteria are colorless plants containing no chlorophyll. How does this make them different from green plants?

2. Unwelcome Organisms

If you have ever had a cold, your body has been attacked by unwelcome organisms. Most colds last only a short time, that is, it usually takes your body only a short time to overcome the organisms that cause a cold. Overcoming attacks by other organisms may take a longer time. What are some of these organisms?

Nongreen Plants

Bacteria are colorless plants; they have no **chlorophyll**, the green substance found in most plants. Since they have no chlorophyll, bacteria cannot make their own food. They cannot capture the sun's energy as green plants do, so they must get their energy from other living things.

Bacteria are living cells. Like other living cells, they have **cell membranes** on the outside. In addition to a cell membrane, bacteria also have a tough **cell wall** which protects the inside of the cell.

Since a bacterium does have a cell wall, how does food get inside? How do bacteria break down solid food into particles small enough to pass into the bacterial cell?

Bacteria do this in much the same way as do **molds** and other **fungi** (fun'jī). Fungi (the plural of **fungus**, fung'gəs) are nongreen plants. Many fungi grow larger than bacteria, but, like bacteria, these fungi have no chlorophyll. They cannot manufacture their own food and must get

their nourishment from other living things. Some common *fungi* are bread mold, mushrooms, and puff balls.

Molds grow in colonies similar to bacteria. They absorb food in much the same way.

To get an idea of how bacteria collected from the air may cause disease, you can use a substitute, a common mold, in the investigation on the opposite page. The way a fungus plant gets its food will give you a clue as to how bacteria may cause disease.

The Needs of Fungi

From your investigation, what would you guess are the needs of bacteria, molds, and similar plants? They need a source of *food*, a source of *moisture*, and a *reasonable temperature*. Molds and bacteria grow well at room temperature. Recall your investigation on page 101. Did the bacteria do well in the refrigerator?

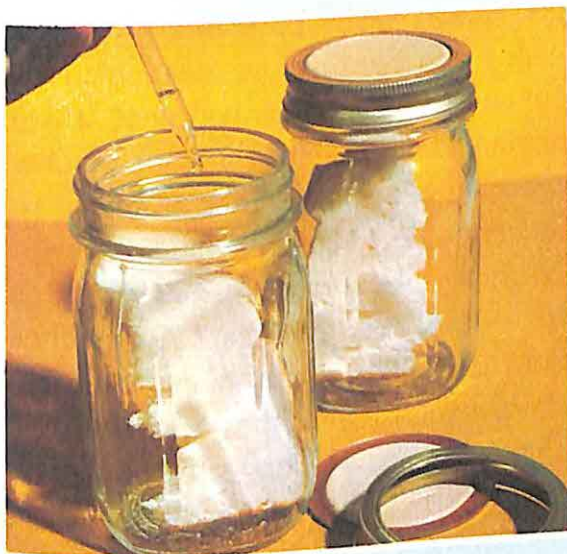
What happened to the bread on which the bread mold was growing? Left for a period of time there should be less and less of the bread. As the mold continues to grow, the bread may disappear altogether.

You can explain the change this way. There was an increase in the amount of bread mold. There was a decrease in the amount of bread; the bread had the substances which were needed by the mold for its growth. As the mold grew, the amount of bread decreased. How could the mold absorb the bread?

AN INVESTIGATION into How Fungus Plants Get Their Food

Needed: two dishes (or jars) and covers;
some stale bread; a microscope

To grow bread mold, obtain two dishes or jars, with covers. Jars with a screw-top cover will do. Be sure the jars are dry. Break a slice of white bread in half. (Use stale bread, or toast both pieces until they are dry.) Put one piece of bread in each jar. To one piece of



bread add about ten drops of water; add no water to the other. ■ Then screw the cap on each jar.

Put both jars in a dark place at room temperature. Examine each jar every day, and make notes of what you see. ●

Examine some bread mold under the microscope. You will see (as shown in the picture) what looks like a bunch of threads. ▲ Each thread has a black ball-like body at one end, which produces **spores**. Each spore can produce a new mold plant.

At the other end of the threads are rootlike structures. Each mold is joined to others by threads that run along the bread.

Do your results agree with those shown? Which one of your jars had the best growth of mold? Why?

AN INVESTIGATION into the Use of Diastase

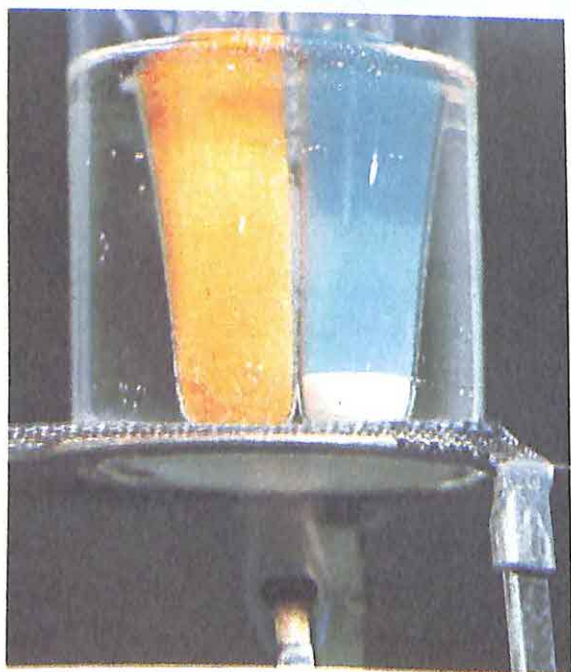


Needed: bread, as a source of starch; diastase (available at the drug-store); Benedict's solution; a test tube; a source of heat

Plan an investigation to show that diastase acts on starch as saliva does. Your plan must show that diastase breaks down starch. Starch will not dissolve in water. It cannot pass through a cell membrane. Sugar does dissolve in water. It can easily pass through a cell membrane. For this investigation on the action of diastase you will need a way of testing for sugar. ■ ● Your teacher probably has some Benedict's solution on hand. If not, it can be bought at most drugstores. How can Benedict's solution be used to test for sugar? A reference book in the library may help you to find the answer. Bread is mostly starch. How can bread mold change the starch so that it can be absorbed through the cell membrane?

Some plans for investigating the use of diastase are shown on the opposite page. Plan an investigation of your own.

On page 119, you will find Sir Alexander Fleming's design for an investigation. Is your plan similar? Does it include a control?



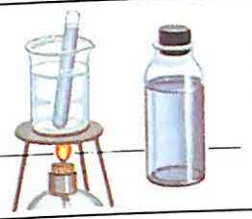
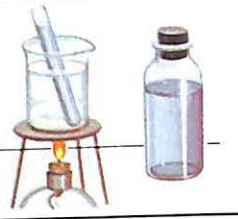
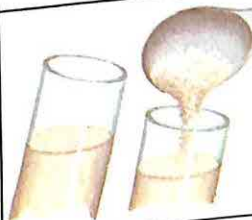
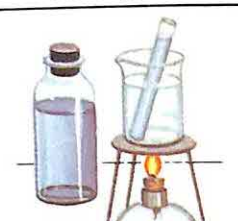
Bread contains starch, a food substance which does not dissolve in water. A substance must dissolve in water in order to pass through a cell membrane. The bread must be broken down in some way so that it dissolves. Then it can pass through the cell wall and cell membrane.

If you could examine (under the microscope) the bread around the rootlike structures, you would see a clear space as if the bread were being dissolved. Actually, the bread is being

digested. To *digest* means to break down food so that it can diffuse through cell membranes. How does mold break down the bread?

In most drugstores, you can buy diastase (dī'ə-stās). Diastase is one of a class of substances called **enzymes** (en'zimz). Some enzymes help to break down the starches in food and to change them into sugars. Can diastase change starch into sugar also? You can find out by doing the investigation on the opposite page. ■

■ POSSIBLE INVESTIGATIONS WITH DIASTASE

A				
	1. test tube of undissolved starch in water	2. add diastase	3. test for sugar	
B				
	1. two test tubes of undissolved starch in water	2. add diastase to one	3. test both for starch	4. test the one with diastase for sugar
C				
	1. two test tubes of undissolved starch in water	2. add diastase to one	3. test both for sugar	4. test a mixture of plain diastase and water for sugar

Did you plan an experiment similar to any of those shown?
Which of the three experiments above will best show what diastase does?

A Bacterium and Its Food

A bacterium digests food in much the same way as a mold plant. It produces enzymes which break down food substances into simple compounds, such as sugar. These simple compounds dissolve in water. Then they can pass through the cell membrane into the cell.

A mold plant can grow and produce spores, and each spore produces another mold plant. A bacterium, on the other hand, grows and divides into two. ■ Bacteria multiply very quickly, sometimes as fast as once every 20 minutes. So a single bacterium falling on the food mixture (bouillon in gelatin), described on page 101, divides into two, the two divide to make four, the four to make eight, and so on. Suppose the number doubled every 20 minutes. How many bacteria would there be at the end of 24 hours? The answer should explain why it does not take long to produce a colony.



When decay bacteria or molds collect and grow on a dead tree, the wood soon begins to rot or decay. The molds and bacteria secrete enzymes which break down the wood of the tree. They use the digested wood as food. They feed, and grow, and reproduce; and, in time, there are enough of them to consume the entire tree.

Bacteria occur in countless numbers and are found almost everywhere—in air, water, and soil. Individually they are so small as to be invisible to the unaided eye, but they are of very great practical importance. In the soil they make nitrogen available to plants. They are the chief agents of decay of dead plants and animals. They are essential in many industrial processes and are the source of many valuable substances. But bacteria are often harmful, too. They are responsible for the spoilage and loss of vast amounts of foods and are the cause of many serious diseases.

Sometimes harmful bacteria fall on an open wound and begin to feed on the cells inside the cut. They grow and multiply very rapidly and soon begin to spread around the entire area. **Infection** occurs. The infection may even invade the blood stream. How could you prevent the growth of bacteria in a wound? How could you stop it?

Various sanitary practices, such as cleanliness, disinfection, and sterilization are common aids in preventing infection; and even your body has ways of defending itself.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Unlike geraniums, bacteria have
 - a. no chlorophyll
 - b. chlorophyll
2. Bacteria are very much like
 - a. animals
 - b. molds
3. Most bacteria grow well at
 - a. the temperature of ice
 - b. room temperature
4. Before food can pass through the cell membrane of a bacterium, it must be
 - a. digested
 - b. starchy
5. To digest food outside its cell membrane, a bacterium uses
 - a. enzymes
 - b. roots

B. Write a paragraph or two on this topic: How a Bacterium Gets Its Food.

**USING WHAT
YOU KNOW**

1. How do bacteria break down a dead tree?
2. How do bacteria reproduce?
3. What may happen when certain bacteria get into a wound?

ON YOUR OWN

Suppose a bacterium divides in a half hour. Then the two resulting bacteria divide in a half hour. At this rate, how many bacteria would there be in 72 hours?

At this rate, why do bacteria not keep on dividing and cover the earth?

3. Your Body's Defenses

There are bacteria everywhere, or so it seems. Why are you not ill all the time? Why is not everyone ill? One reason is that the body is on the defense all the time.

The First Line of Defense

How is the inside of a house protected from the rain? By its roof and walls, of course. When there is a break in the window or a hole in the roof, the rain gets in; so can certain living things, insects, for instance.

How is your body protected against invasion by bacteria or other infectious organisms? You are protected by a covering of skin. The skin is the first line of defense on the outside of your body and is made up of layers of cells. It is almost waterproof; and unless it is broken, it is practically germproof.

There is a layer of flat cells on the outside of the skin. This layer is not dry but is almost always covered by a thin layer of moisture from perspiration. Perspiration helps also to protect the body against bacteria. Bacteria that stick to the moist skin are removed when you bathe. You wash away many of the bacteria with soap and warm water.

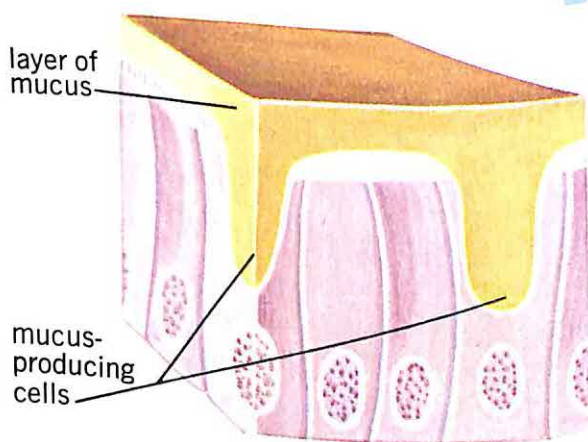
What about the inside of your body? How is it protected? There, too, you will find cells that hold the line of defense against bacteria. The **covering cells** line the inside cavities of the body. These areas could be

reached easily by **infectious** bacteria, but the protective cells have an extra way to defend the body. You can investigate this personally.

Wash your hands until they are quite clean and feel the inside of your cheek. The covering cells inside your mouth are moistened with saliva—a substance containing much water and a sticky fluid. That sticky fluid is important.

These covering cells inside the body have another kind of moistness from a substance called **mucus** (*myōō'kəs*), as shown in the picture. ■ Mucus is **secreted** from the cells which line certain cavities inside the body, such as the mouth, throat, nose, food tube, and tubes which lead to the lungs. When a substance is produced *inside* the cells and used *outside* the cells, we say it is secreted by the cells.

Some covering cells secrete mucus which forms a protective coating. Certain other cells secrete other substances, such as the digestive juices. Digestive juices kill many bacteria that are swallowed with our food.



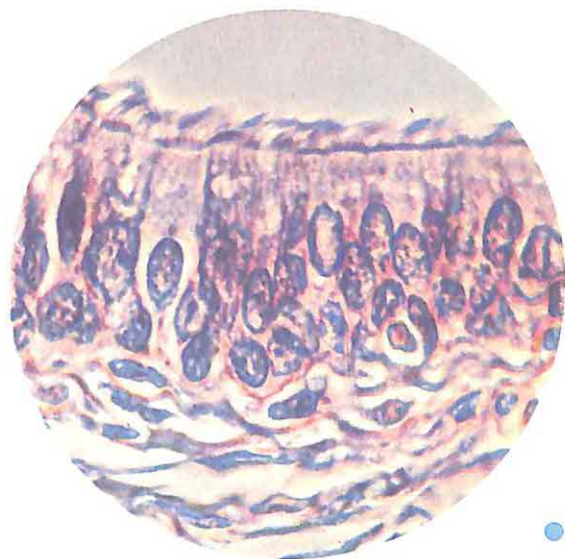
How does mucus help defend the body against bacteria? If you were to shake some ground pepper on a moist plate, the idea would be clearer to you. Just as pepper sticks to the film of water on the plate, the bacteria stick to the mucus. Does this help to explain what happens to bacteria which get into your nose and throat?

Do you ever sneeze or cough? Sneezing and coughing are reflexes that help get rid of bacteria. When you breathe, bacteria and other harmful substances are caught in the mucus of the nose and throat. They are removed from the body by sneezing and coughing.

If you were to use a microscope to look at the cells which line the wall of the windpipe, you would see special kinds of cells like the ones in the picture. ● These cells have tiny hair-like parts, called **cilia** (sil'ē.ə). The cilia move the way oars move when you row a boat. They push bacteria that are caught in the mucus back up into the throat. Then a sneeze or a cough sends them out of the body. This should explain why you should use a handkerchief when you sneeze or cough.

Getting Rid of Bacteria

You breathe in bacteria. You swallow them with your food; but it is hard for them to get past the cells that line the inside of your body. There are lining cells that secrete mucus to catch the bacteria. Cells lining your windpipe have cilia which push back



the bacteria. Then, of course, sneezing and coughing, two reflexes, help to throw many of the invading bacteria out of your body.

But suppose the skin, the mucus, and your body reflexes fail to get rid of the bacteria. What then?

Suppose bacteria get past the windpipe and into the stomach. What protection do you have? The investigation on the next page will help you to find the answer to that question. Be sure to control all the variables.

Sometimes you may scrape or cut yourself and break the skin. This gives the bacteria a chance to get past the first line of defense. Suppose you do not wash the cut thoroughly with soap and water. Suppose you do not use an **antiseptic** (an'tə-sep'tik). Antiseptics are substances that stop the action of bacteria or kill them completely. What happens to the cut? What can you do about infection? What can your body do?

AN INVESTIGATION into What Happens to Bacteria in the Stomach



Needed: weak hydrochloric acid; gelatin for growing bacteria (such as you made on page 101); four dishes

Stomach cells secrete a digestive juice that contains an **acid**. It contains weak hydrochloric acid (hī'drə-klôr'ik as'id), a solution of hydrogen chloride.

Make enough of the gelatin mixture to pour about an inch into each of the four dishes. When the gelatin has congealed in each dish, put a quarter inch of water over the top of the gelatin. Add ten drops of weak hydrochloric acid, which your teacher will give you, to two of the dishes; add ten drops of water to the other two dishes. ■ These are the controls. You can use them to compare your results.

Now let the bacteria grow. Cover the dishes and put them in a warm place, a closet perhaps. ● In which dishes do you expect to find large colonies? ▲ In the ones with acid?

What *do* you find? (If your results are not as you expected, what might be the explanation?)

Were all the variables controlled?





Fighting Infection

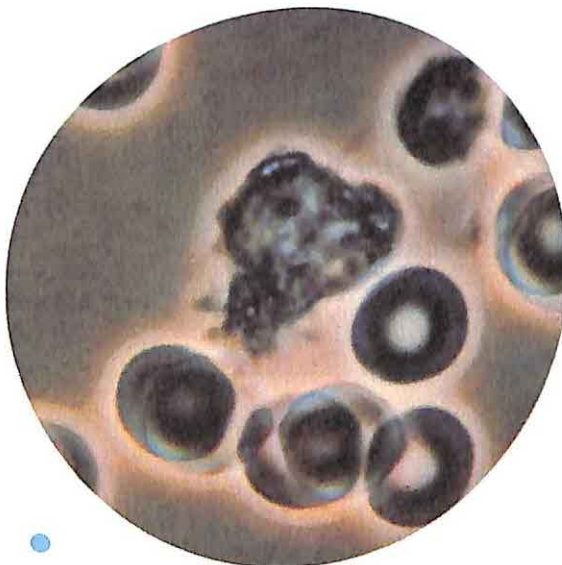
A cut that becomes infected is white or yellowish in color, in addition to being surrounded by an inflamed red area. What gives an infected cut its color?

Under the microscope, the material in an infected cut looks like that shown in the picture. ■ Notice the tiny bunches of black dots. These are

a special kind of bacteria, which cause many common infections and can be very resistant to treatment. The name for this bacterium is *Staphylococcus* (staf'ə-lō-kok'əs), staph, for short. Recall that all ball-shaped bacteria are called cocci.

The larger cells in the picture are special ones that are found in the blood, the **white blood cells**. They are easy to recognize in a drop of blood when viewed through a microscope. They move in a strange way. They move by extending what are called false feet, but which are really more like false fingers.

Look at the pictures of a white blood cell that were made using a camera attached to a microscope. ● ▲ It was photographed as it was moving. It seems as if a white blood cell extends a part of itself as a kind of finger in one direction, and another part of itself as a second finger in another direction. The white cell





moves along in this manner and surrounds the bacteria. The bacteria are absorbed into the body of the white blood cell.

The pictures show how a white cell takes in bacteria. ■ ● When it does so, the white cell engulfs, or surrounds, the bacteria with its body and then digests them. The bacteria are destroyed. ▲

Sometimes it is possible to prevent harmful bacteria from entering the blood through an open cut. What can you do to keep bacteria out?

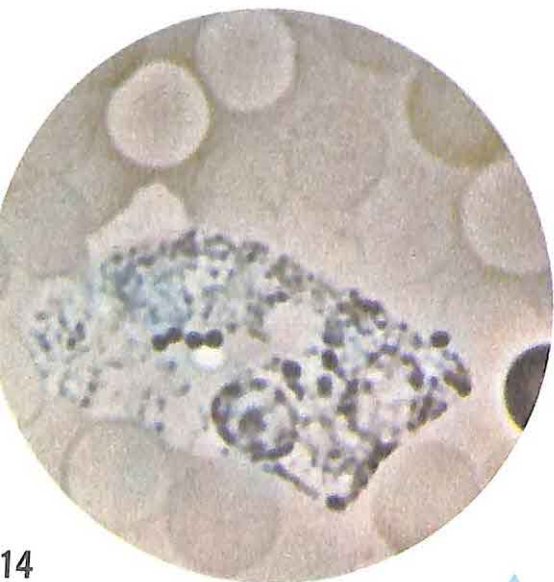
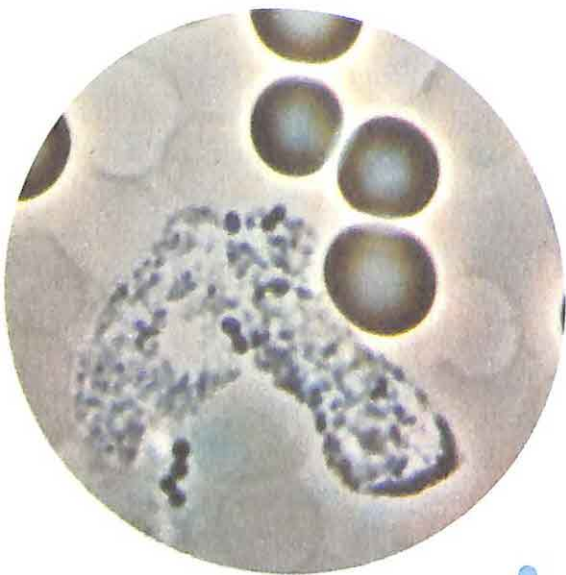
What should you do when you cut yourself? Wash the wound with soap and water, of course. Doctors recommend washing the cut carefully and, perhaps, adding a drop or two of antiseptic. (Whenever it is possible, show the cut to your parents or your teacher before treating it yourself.) Your doctor or your school nurse can give you the names of some good antiseptics.

What does an antiseptic really do? To find out try the investigation on the opposite page.

When Body Defenses Fail

Suppose you do not wash a cut or use an antiseptic in time or suppose the antiseptic does not work.

Suppose the white blood cells are unable to kill all of the harmful bacteria. Sometimes the white blood cells are overcome by poisons produced by the bacteria. What then? Is the battle lost? Not necessarily, in modern times, as you will discover.



AN INVESTIGATION into How to Keep Bacteria from Growing

Needed: a few flat dishes (Petri dishes); some antiseptics, such as Iodine (your druggist can supply several different kinds of antiseptics); food-gelatin mixture (p. 101)

Pour the food-gelatin mixture into the dishes. Allow it to cool (exposed to the air) for several hours as you did in the investigation on page 101. To one dish, add enough water (boiled and then cooled) to cover about half of the gelatin. This first dish is your control. All of the others should test for one variable each. They can be compared to the control.

Add a few drops of a different antiseptic to one of each of the other dishes. ■ With the boiled water, cover the gelatin in each dish about halfway to the top of the dish, as you did before. Place all the dishes in a warm place.

What is the result after one day? after two days? after several days?

Did you get the results shown in the pictures? ● ▲

Most microorganisms do not grow when an antiseptic is used on them. The same thing happens when an antiseptic is applied to a cut.



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The first line of defense that the body has against infectious bacteria is the
 - a. skin cells
 - b. blood cells
2. The covering cells inside the body produce and secrete a fluid called
 - a. mucus
 - b. Staphylococci
3. In the stomach, a defense against bacteria is
 - a. acid
 - b. food
4. Which one of these reflexes helps to get rid of bacteria?
 - a. yawning
 - b. sneezing
5. When the skin is broken, we can defend the body against infection by applying
 - a. enzymes
 - b. antiseptics
6. In the blood, the cells which destroy bacteria are the
 - a. red cells
 - b. white cells

B. Write a paragraph or two on this topic: The Body's Defenses. Explore sources other than your textbook for additional information.

**USING WHAT
YOU KNOW**

1. Why is it important to keep the skin clean?
2. Why is it important to wash a bruise clean with mild soap and water?
3. Why is mucus more effective than water in catching bacteria?
4. Not all bacteria are harmful. What useful purposes do they serve?
5. In what ways are molds and bacteria related? In what ways are they different?

A. Design an experiment that will answer the following questions:

Do antiseptics destroy molds?

How can you be sure that the mold would not die even without the antiseptic?

How can you be sure that it is the antiseptic that keeps the mold from growing?

Grow some bread mold, as you did on page 105. Then design an investigation to determine whether an antiseptic (one of the iodine products, for example) will kill the mold. You may want to get samples of some of the many advertised brands of antiseptics and mouth washes to find out how effective they are. Design your experiment so that all of the variables are controlled.

B. Get a copy of the *American Red Cross First Aid Textbook*, and study it carefully. Find the best methods for treating injuries.

4. Molds to the Rescue

In the year 1928, one day began like any other day, but it did not end that way. It became a "red letter" day for Dr. Alexander Fleming (later knighted as Sir Alexander Fleming). He had gone to work in his laboratory. Sir Alexander was a bacteriologist (bak·tir'ē·ol'ə·jist). Bacteriologists study the structure and behavior of bacteria.

He grew colonies of bacteria in much the same way as you grew them in the investigation on page 101. As a bacteriologist, he tried to isolate pure colonies of bacteria. (A pure colony contains only one kind of bacterium.) That is, he tried to study only one kind of bacterium at a time, perhaps

a kind that caused a certain disease, for instance. To do this, he used a special type of broth or gelatin which he put into a culture dish. He had to work with great care to keep all other organisms, except the kind he was studying, out of the dish. Sometimes, no matter how careful he was, organisms that did not interest him got into the dishes. Many of these unwelcome visitors were molds.

Several days before this special day in 1928, Dr. Fleming opened the lids of some culture dishes containing a certain kind of bacterium. He prepared a slide with some of the bacteria to observe with the microscope. For a few moments while he prepared the slide, the gelatin mixture in the dishes was exposed to the air.

When Dr. Fleming examined another sample of bacteria later, on this special day in 1928, he became very curious. One of the culture dishes had a growth of *Penicillium* (pen'ə-sil'ē-əm), a bluish-green mold; but the thing that Dr. Fleming became excited about was this: Around the growth of mold there was a clear space. *Almost no bacteria grew in this space. Why?*

For a long time, scientists had suspected that some plants secrete substances that can be used to kill bacteria in the human body. This was an exciting idea: that some plants can secrete substances that can be used against other plants like bacteria. Sir Alexander's observation of the growth of *Penicillium* (a plant) and the clear space around it led him to wonder whether *Penicillium* was producing such a substance.

Dr. Fleming observed that the *Penicillium* mold *seemed* to make a substance that destroyed bacteria. He found it easy to grow *Penicillium*; it is also easy to grow bacteria. He should find it easy to test his idea. How could he *prove* that *Penicillium* produces a substance that kills certain kinds of bacteria? How could he prove that such a substance would not harm the human body?

Sir Alexander's Investigation

It is important to know what Sir Alexander *did not do*, as well as what he *did do*. He *did not* take his first observation as proof that *Penicillium*

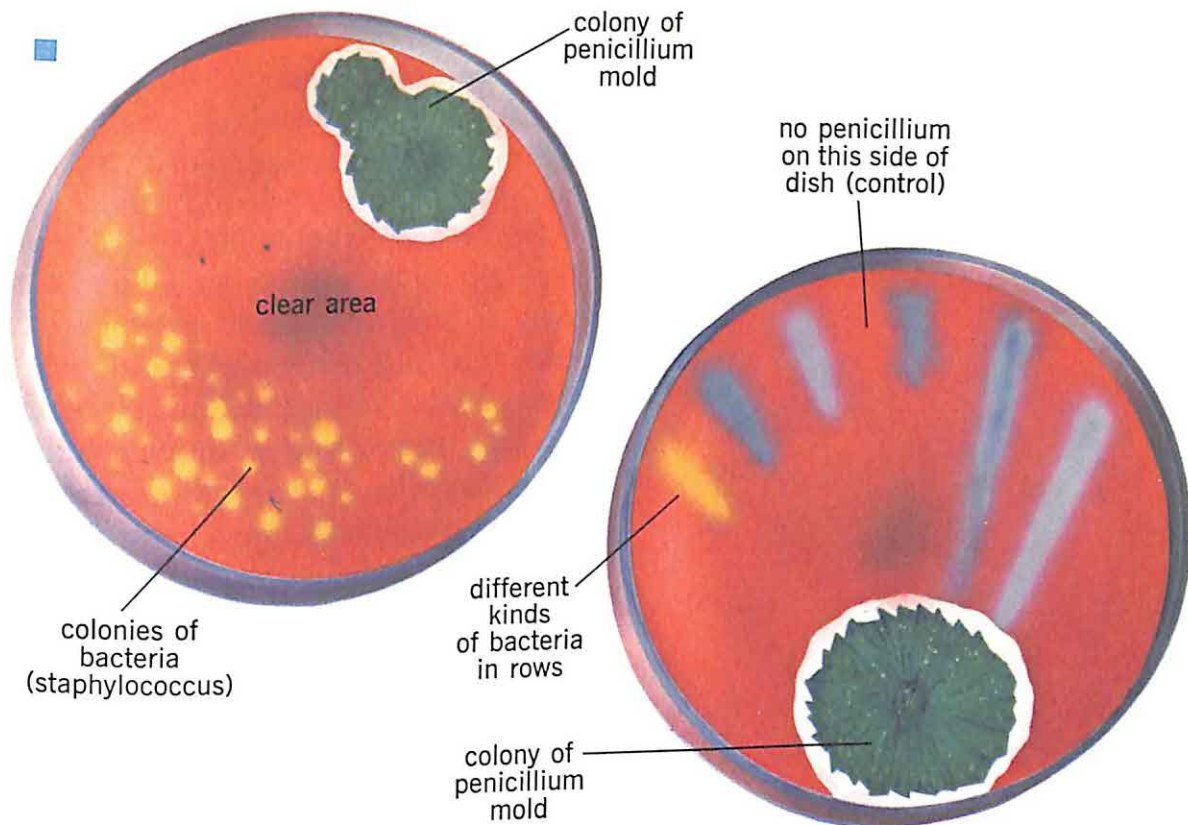
produced a substance which stopped the growth of bacteria. He *did not* come to a conclusion from only one observation.

Recall the situation: One day in 1928, Sir Alexander Fleming observed what had happened to some of his colonies of bacteria. He saw the mold *Penicillium* growing in one of his dishes; and there was a clear ring around the mold. Almost no bacteria were growing in that clear ring.

Sir Alexander made a sketch of the dish, and wrote down his observation. He must have hoped that his interpretation of what he saw was correct, because if what he saw were true, it would have great usefulness. Any man would have been excited at such a great discovery.

Whatever he might have thought, Sir Alexander decided to try to find out whether or not *Penicillium* produces a substance which destroys certain kinds of bacteria. He set about designing an **experiment**.

The *experiment* is a great tool of the scientist. In an experiment, the scientist tries to set up the conditions in the laboratory in such a way that he can *control* what happens. Outside, there are too many things happening at once to isolate one specific cause and effect. If he designs his experiment carefully enough, it may yield data which will help him to find the answers to his questions. However, his experiment may not yield the results he expects; it may only indicate the need for further experiments.



Fleming started with a working idea based on what he had seen. He was not working in the “dark,” as we say. A working idea that helps a scientist plan, or design, an experiment is called a **hypothesis** (hī-poth’ə-sis). Fleming’s hypothesis may have been: *Penicillium* produces a substance which destroys some kinds of bacteria. The experiment I need to design should provide conditions that show, without doubt, that certain bacteria do not grow where *Penicillium* grows.

His experiment was therefore designed to: ■

1. Grow different kinds of bacteria in pure culture in lines on plates.
2. Grow *Penicillium* in pure culture.
3. Introduce *Penicillium* on one side of the plate at one end of each

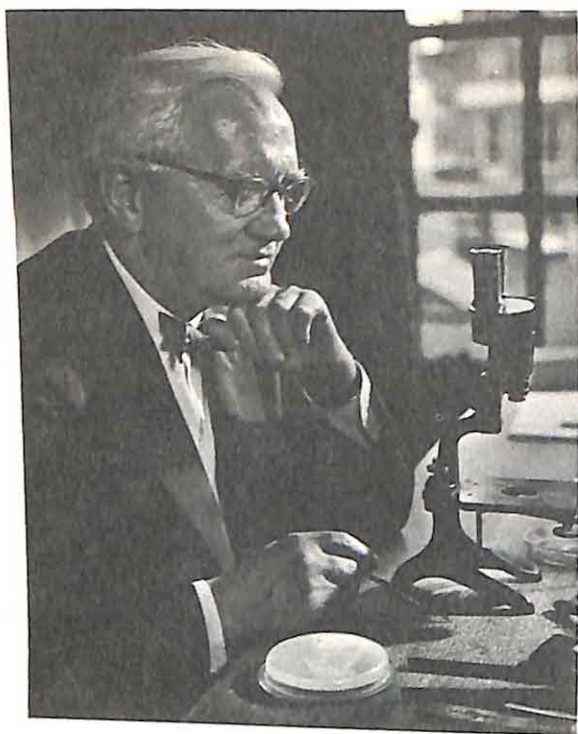
line of bacteria. Do this on 100—or perhaps even 1,000 plates; *one* investigation is not enough.

4. Do not place *Penicillium* on the other end of each line of bacteria. This is the **control**. In a control, the *thing the scientist wants to study* is usually left out.

5. Allow the bacteria to grow in exactly the same surroundings, except that some bacteria are near the *Penicillium*, and others are not.

If Dr. Fleming’s hypothesis was correct, and if his experiment was designed correctly, then:

1. The bacteria in contact with the *Penicillium* should not grow.
2. At the ends of the rows of bacteria where there was *no Penicillium* growing, the bacteria should grow.



This is exactly the result Sir Alexander Fleming found in some of the rows. He repeated the experiment in *many different ways* and at *many different times*. He kept careful written records and photographed his results. ■ *Other scientists repeated his experiment.*

He finally was able to show conclusively that *Penicillium* does produce a substance which destroys *certain kinds* of dangerous bacteria. He also performed other experiments that showed that **penicillin** (the substance derived from *Penicillium*) was not harmful to higher animals.

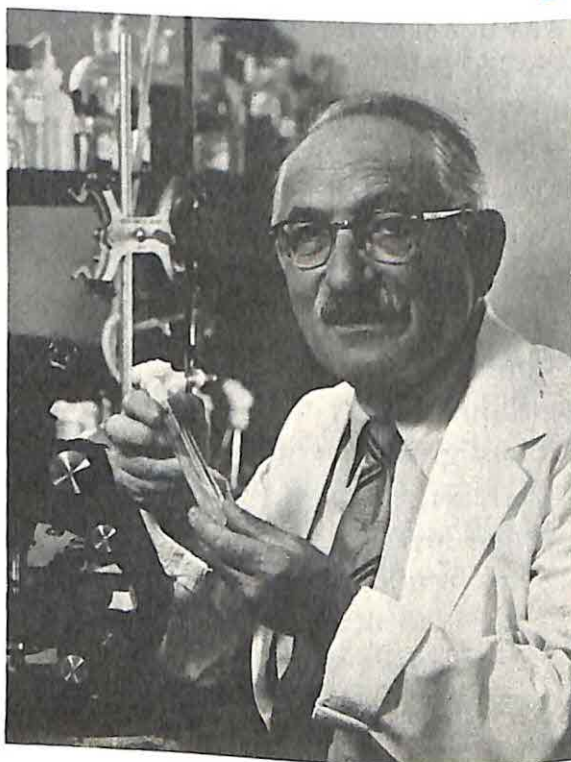
Other scientists, before Sir Alexander, had suspected that molds produced such substances. Some had even written about their ideas; but Sir Alexander designed the experi-

ment which *proved* that these substances secreted by molds would destroy certain bacteria.

A Successful Experiment

When Sir Alexander Fleming proved that *Penicillium* produces a substance that kills some kinds of bacteria, he called it penicillin. He also found, by injecting it into animals, that penicillin is generally harmless to higher animals; but it took many years and the help of many scientists to find a way to produce large amounts at a reasonable cost.

Penicillin kills many kinds of harmful bacteria. Should your body, with its natural defenses, be unable to throw off any of these kinds of bacteria, your doctor may give you penicillin to help control them.



Two other scientists, Dr. Howard Florey and Dr. Ernst Chain, aided Dr. Fleming; they found a way to purify penicillin to make it safe for man to use. For their great contribution, the three scientists were awarded the Nobel prize. The Nobel prize is perhaps the greatest prize that scientists can receive for their work—except, perhaps, the personal satisfaction which they get from doing the work.

Penicillin, however, is not effective against *all* kinds of bacteria, so the search for other beneficial molds began. Soon Dr. Selman Waksman, an American scientist, extracted another substance from a mold. ● He called it **streptomycin** (strep'tō-mī'sin). It is more effective for killing certain types of bacteria than is penicillin.

That is especially true when streptomycin is used to destroy the bacteria that cause tuberculosis.

Today there are many different substances extracted from molds which help kill bacteria. These substances are called **antibiotics** (an'ti-bī-ot'iks). Antibiotics are not the same as antiseptics. Antibiotics are chemical substances which are secreted by living things. Many diseases and common infections are now being conquered by antibiotics. ▲

Scientists have discovered how to make the body a poor environment for bacteria by introducing antibiotics. Because of the work of scientists like Sir Alexander Fleming, it is very likely that you will live longer than your ancestors did.

SOME COMMON ANTIBIOTICS

Name of Antibiotic	Helps destroy disease germs causing
Achromycin	Ear, sinus, and throat infections, bone infections, pneumonia, scarlet fever, meningitis, undulant fever
Aureomycin	Virus pneumonia, typhus fever, Rocky Mountain spotted fever
Chloromycetin	Parrot fever, rabbit fever, typhus fever, one kind of pneumonia, smallpox, and many more bacterial and virus diseases
Erythromycin	Certain diseases such as typhus, virus diseases, and others
Penicillin	Pneumonia, colds, boils, gas gangrene, epidemic meningitis, kidney and bladder infections, and many more bacterial diseases
Streptomycin	Tuberculosis, rabbit fever

Your Own Investigation

Sir Alexander Fleming wondered why there was a clear area around a mold. Because he was a *trained* scientist, he not only wondered, but took the question to the laboratory. There he worked very long and very patiently, until he had the evidence he was looking for. In planning your investigation into what diastase does

(suggested on p. 107), did you have a *hypothesis*? and a *control*?

Did you begin to design your experiment around a clearly stated hypothesis? Sir Alexander's was: *Penicillium* produces a substance which destroys some kinds of bacteria. What was your hypothesis?

How close was the plan of your experiment to that of Sir Alexander's?

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Sir Alexander Fleming discovered an
 - a. antiseptic
 - b. antibiotic
2. Penicillin is produced by
 - a. a plant
 - b. an animal
3. Penicillin was first tested on
 - a. men and women
 - b. rabbits
4. In designing his investigation, Fleming planned an experiment. In an experiment a scientist tries to
 - a. control the conditions
 - b. let many things happen
5. The working idea that helps a scientist plan or design an experiment is his
 - a. hypothesis
 - b. experimental design
6. When a scientist sets up an experiment to include a situation where the one thing he wishes to study is left out, that part of the experiment is the
 - a. proof
 - b. control
7. Before scientists accept the result of an experiment, the experiment is
 - a. repeated many times
 - b. published

8. Like penicillin, streptomycin is an
- a. antibiotic b. antiseptic

B. Write several paragraphs on one of these topics:
 Sir Alexander Fleming Penicillin
 The Importance of a Controlled Experiment

USING WHAT YOU KNOW

1. Iodine has been used for many years as an antiseptic that quickly kills bacteria. With antiseptics available, why did scientists find it necessary to search for antibiotics?

2. A girl found some green mold growing on a piece of bread. She wanted to find out whether the green mold grew best in a moist or a dry environment. She divided the piece of bread so that there was about the same amount of mold on each piece. Then she put one piece of bread in a moist environment, the other in a dry environment. Both of the pieces had a good growth of mold. Was she justified in reaching the conclusion that bread mold grows equally well in both a moist and a dry environment?

ON YOUR OWN

There are a good number of antibiotics in use today. You know a little about penicillin and streptomycin.

Do some additional research in the library to find the answer to this question: *Which antibiotics are used against the major diseases?* Put your findings in a table, as shown. ■

Antibiotic	Discoverer	Uses
Penicillin	Alexander Fleming	
Streptomycin	Selman Waksman	Mainly against tuberculosis



5. Another Battle: Another Victory

The *enemy* in this story is a **virus** (vī'rēs), not a bacterium. Viruses are still another type of invisible killer. A virus is even smaller than a bacterium, as the picture shows. ■ Some viruses are so small that they can live inside bacteria, in somewhat the same

way that bacteria can live inside people. You can see most bacteria under a good ordinary microscope; but viruses are so small that they had never been seen until a special kind of microscope, an electron microscope, was invented.

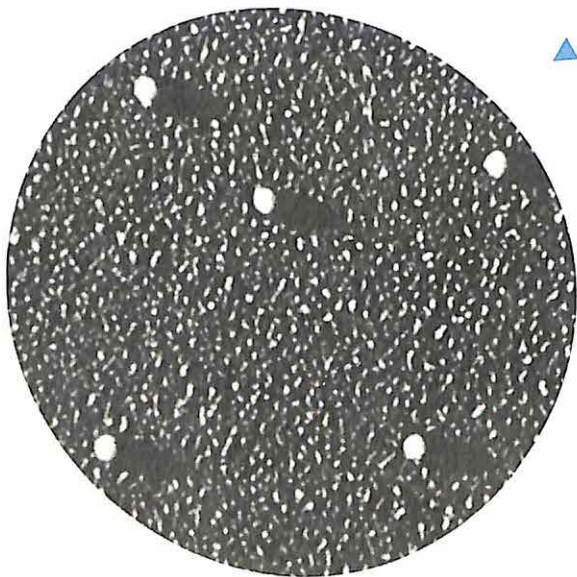
Joseph Meister, whom you read about on page 99, was suffering from a virus. Rabies is caused by one of many viruses.

Among the many different kinds of viruses are those that can cause influenza. ● Many viruses look like tiny spheres, as shown in the pictures.

Polio Virus—The Enemy

This time the enemy is the virus which causes infantile paralysis (in'-fən-tīl pə-ral'ə-sis), or **polio** (pō'-lē-ō), as the disease is called. Look at a picture of the villain. ▲

What does the polio virus do? First of all, it multiplies. Second, in large numbers, it attacks the nerves which

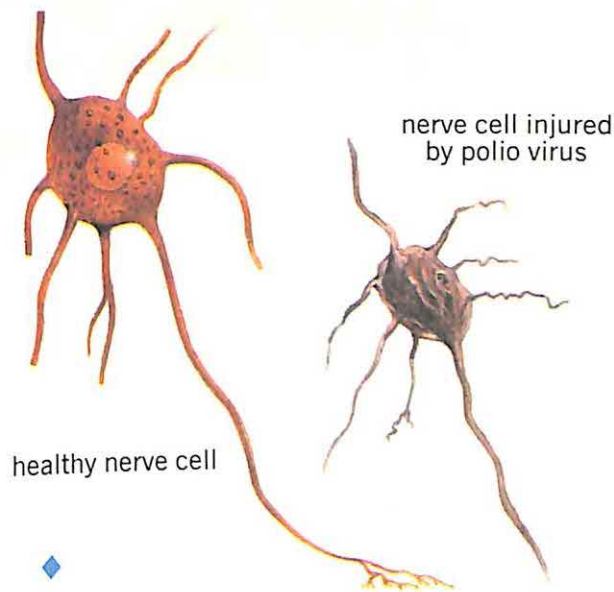


lead to the muscles. The nerves carry impulses to the muscles from the brain and spinal cord. When the nerves are affected so that impulses do not reach the muscles, the muscles cannot move. The picture shows a healthy nerve cell and one which has been attacked by the polio virus. ♦ The polio virus thus strikes at the nervous system. The result is that the muscles cannot function properly. When the muscles do not function or are paralyzed, they become useless. The virus attacks young people as well as adults. Franklin Delano Roosevelt, a former President of the United States (1933–45), was crippled by polio when he was a young man. He fulfilled his duties as President in a wheelchair.

Sometimes the virus attacks the nerve cells leading to the leg muscles. Sometimes it attacks nerves leading to the muscles which control breathing. Then the victim must be placed in an iron lung. ★ The iron lung serves as an artificial means of breathing; the change in air pressure is regulated by a kind of pumping action. It causes the victim's ribs and lungs to expand and contract—to take in air and to push out air.

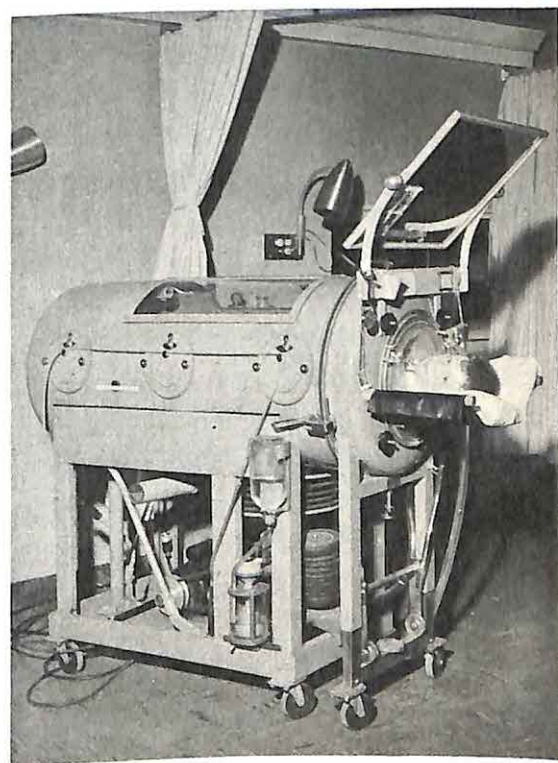
Polio is now on the way out. It will go down in history as another disease which is no longer a menace to man—another example of man's control of his environment.

The virus of smallpox and the bacterium of diphtheria belong in the same category. They can be kept



there only with your help, the help of your parents, and the help of departments of public health.

Why is this so? Read on to see how scientists battle a disease like polio.



The Battle Against Polio

What happens when bacteria or viruses invade your body? They attack in weak moments (when your resistance is low) or in weak places (where a break occurs in the lines of defense). They must get through your first lines of defense, the skin, the film of mucus, and the digestive juices in your stomach. If the bacteria or viruses get through your skin, then the white blood cells attack them; but suppose all these fail. What then? There is, of course, the chemical defense of antibiotics; but that is not all. There is still another chemical defense which scientists have developed to help your body fight disease.

Do you remember being **vaccinated** (vak'sə-nāt-ed) for smallpox? Probably not. Most children are vaccinated against smallpox, a virus disease, when they are very young.

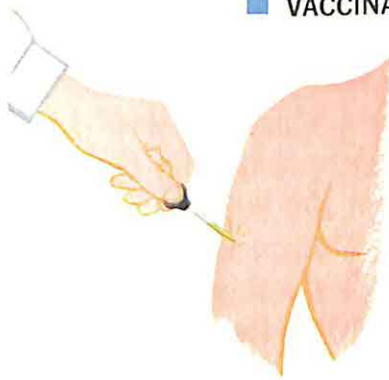
What does the doctor do when he vaccinates against smallpox? He breaks the skin on your arm or leg; then he introduces a bit of cowpox virus into the break. The body reacts to the cowpox virus by producing substances called **antibodies** (an'ti-bod'ēz). Antibodies then destroy the cowpox virus. The antibodies remain in the blood; and because the cowpox virus is very similar to the smallpox virus, the antibodies also destroy smallpox viruses. The illustration shows an artist's view of the conquest of disease. Of course you know that antibodies cannot be seen. ■

Do not confuse *antibodies* with *antibiotics*. Antibiotics are substances produced by molds; they are chemical substances *made outside* the human body but *used within* to fight some kinds of organisms. Antibodies are produced by cells in the human body. When your body makes antibodies to combat a disease, you are said to be **immune** (i-myōn') to that disease. This means that the environment is unfavorable for the growth of the viruses or bacteria that cause the disease. They cannot live when the antibodies are present. Antibodies are specific; that means that a different type of antibody is usually needed to fight each different kind of disease. Antibodies are formed in the body of a person who has had a disease. After the person recovers from the disease, the antibodies usually remain in the blood. Then we say the person has developed immunity against that particular disease, or say he is immune to the disease.

A person who has had typhoid, and recovered, has the antibodies against typhoid in his blood. He is immune to typhoid. If typhoid bacteria enter his body again, the typhoid antibodies destroy them. He does not get typhoid again. This is called *natural immunity*. The same is true of smallpox; but having a disease to achieve immunity is too dangerous. It may even be fatal.

Vaccination is a safer way to produce immunity. Vaccination against smallpox stimulates the body to produce the antibodies to smallpox. After

■ VACCINATION PROTECTS US FROM SMALLPOX



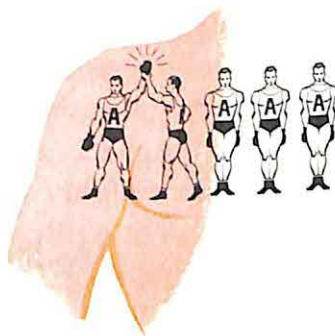
① harmless cowpox viruses are placed under the skin



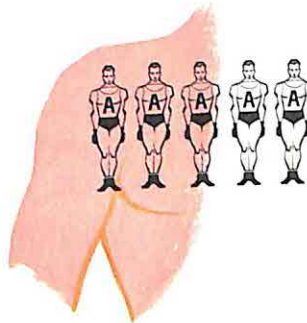
② they cause a blister to develop



③ the body fights the virus by making antibodies



④ the antibodies kill all the cowpox viruses. the blister goes away



⑤ the antibodies stay in the blood



⑥ later... if smallpox viruses enter the body antibodies will kill them immediately

this, the viruses of smallpox which may enter your body are destroyed by the antibodies. You are then immune to smallpox. This is called *acquired immunity*.

The scientist is faced with the problem of finding a way to give a person enough of the disease-producing organisms for his body to produce antibodies; without giving him enough so that he gets the disease. Usually, weakened or dead microorganisms of a specific disease are injected in small doses into a person.

Recall that the **serum** given to Joseph Meister by Pasteur (page 99) already contained antibodies. The

serum came from the spines of rabbits that were infected with rabies. It contained antibodies that were produced in the rabbits as they fought the disease. The antibodies in the rabbits' serum saved Meister's life.

Many scientists fought in the battle against polio, but three men led the fight. To win the battle, it was necessary to produce a **vaccine** (vak'-sēn). The first step advanced when Dr. John Enders learned how to grow the polio virus outside a living organism. He was then able to study its development. He found that a virus becomes weaker if it is grown under certain conditions.



As a beginning in making polio vaccine, Jonas Salk looked for a way to weaken the polio virus so that it could be injected into the body without causing illness. If strong polio viruses were injected into the body, the per-



son might get the disease. Finally, after many years, Dr. Salk discovered that even when the *dead* virus was injected into the body, the body responded by producing antibodies against polio. Many careful tests were made; the Salk vaccine was successful. ■ Polio was on its way out.

The Salk vaccine requires injections by a doctor; but another vaccine, produced by Dr. Albert Sabin and his team of scientists, can be taken by mouth. The Sabin vaccine contains weakened *live* viruses. Both types of vaccine, the Salk and the Sabin, have been thoroughly tested. Both are completely safe. Both enable the body to develop antibodies in the cells. You have probably taken the Salk or the Sabin vaccine. If so, you have antibodies which will kill polio viruses that get into your body. You are immune to polio.

Only half the battle is won in the laboratory. How can the battle against polio virus, or any other germ, be won for all time? First, scientists and doctors fight the battle in the laboratory. The concepts of science are used in the development of an antibiotic or an antibody, but this is not enough. Everyone must cooperate. For instance, once a vaccine has been tested and found safe, the battle is up to us; we must make use of the vaccine.

In the fight against polio, we must all do what the people in the picture are doing: We should take the vaccine. ● Have you taken it?

A Record of Victories

Look at the table below. Study it carefully; it tells an important story. ▲ The scientists, whose names are listed, worked long and hard. Because they did, the bacteria and viruses that are listed in the table can be controlled. The diseases they cause can be controlled by substances that are produced in your body. You develop immunity. Notice how little space the table takes; but it represents the work of many people over a long period of time. What will be next on the list?

Study the table again. How long did it take to bring these diseases under control?

The table tells another very important story. It tells how man, as a scientist, has learned to control another area of his environment. He is able to control many of the invisible organisms which would otherwise make him ill or cause death. He used his ideas; but he also needed such tools as compound and electron microscopes—another example of the partnership of science and technology.

SOME DISEASE GERMS WE CAN CONTROL			
Name of disease	Method used	Scientist(s) who discovered method of control	When
smallpox	vaccination with cowpox virus	Edward Jenner	1796
typhoid	avoiding contaminated milk and water	William Budd C. J. Eberth G. Gaffky	1856 1880 1884
yellow fever	control of mosquito found to spread the disease	Carlos Finlay Walter Reed and others	1881 1900
cholera	avoiding contaminated water and food	Robert Koch	1883
hydrophobia (rabies)	vaccination with antibodies from rabbits	Louis Pasteur	1885
diphtheria	inoculation with antibodies from immune animals	Emil von Behring	1890
malaria	control of mosquito that spreads the disease	Ronald Ross Battista Grassi	1898
bubonic plague	destroying rats which carried fleas that spread the bacteria	Plague Research Commission, India	1905
polio	vaccination with weakened or killed polio virus	John Enders Jonas Salk Albert Sabin	1949 1954 1960

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Substances produced by an animal inside its body that can destroy bacteria or viruses that get into the body are
 - a. antibiotics
 - b. antibodies
2. If a person is vaccinated with the cowpox virus, his body produces substances which can destroy
 - a. the smallpox virus
 - b. typhoid bacteria
3. The serum given to Joseph Meister contained
 - a. antiseptics
 - b. antibodies
4. Jonas Salk proceeded with the work begun by John Enders to combat
 - a. polio
 - b. tuberculosis
5. The difference between the Salk and Sabin vaccines is that the Sabin vaccine uses
 - a. weakened, live viruses
 - b. dead viruses

B. Write several paragraphs on this topic: Antibodies.

**USING WHAT
YOU KNOW**

1. What are the differences in these three defenses against bacteria:
antiseptics antibiotics antibodies
2. What is the difference between natural immunity and acquired immunity?

ON YOUR OWN

1. Do some investigating in the library. Find out what you can about the lives of
 - Louis Pasteur
 - Jonas Salk
 - Albert Sabin
2. What kind of polio vaccine is used in your town?

6. Health—A Public Concern

You drink water every day with no concern about getting diseases from bacteria in the water. Yet, there was a time when cholera (kol'ər-ə) and typhoid, two diseases which are carried by water, killed many people.

You drink milk without the slightest worry. Yet, milk was once the carrier of many diseases, among them tuberculosis. Today, it would be unusual to find diseases spread by milk; milk is safe to drink.

Safe drinking water and pasteurized milk are things we take for granted. Who is responsible for your protection, and how?

You turn a faucet and water pours out. Where does the water come from, and how do most cities make sure the water is safe to drink?

The glass of water you drink probably came from a cloud. When the

water vapor in a cloud condenses, it falls to earth as raindrops and finally reaches a stream. The stream may lead to a **reservoir** (rez'ər-vwôr). Reservoirs are large lakes used for storing water. Water used by most large cities collects in reservoirs.

A reservoir should be located in clean surroundings, away from the city, where the water is not contaminated with wastes from factories, garbage, and sewage. Why is it important for the reservoir shown in the illustration to be fenced in? ■

Even under the best conditions, however, lake water or river water is not free from harmful microorganisms. As water flows along the ground, it can pick up many impurities. Water can pick up all kinds of bacteria and other organisms from its surroundings. How can it be purified so that it is fit to drink? How can *harmful* bacteria be removed or destroyed?



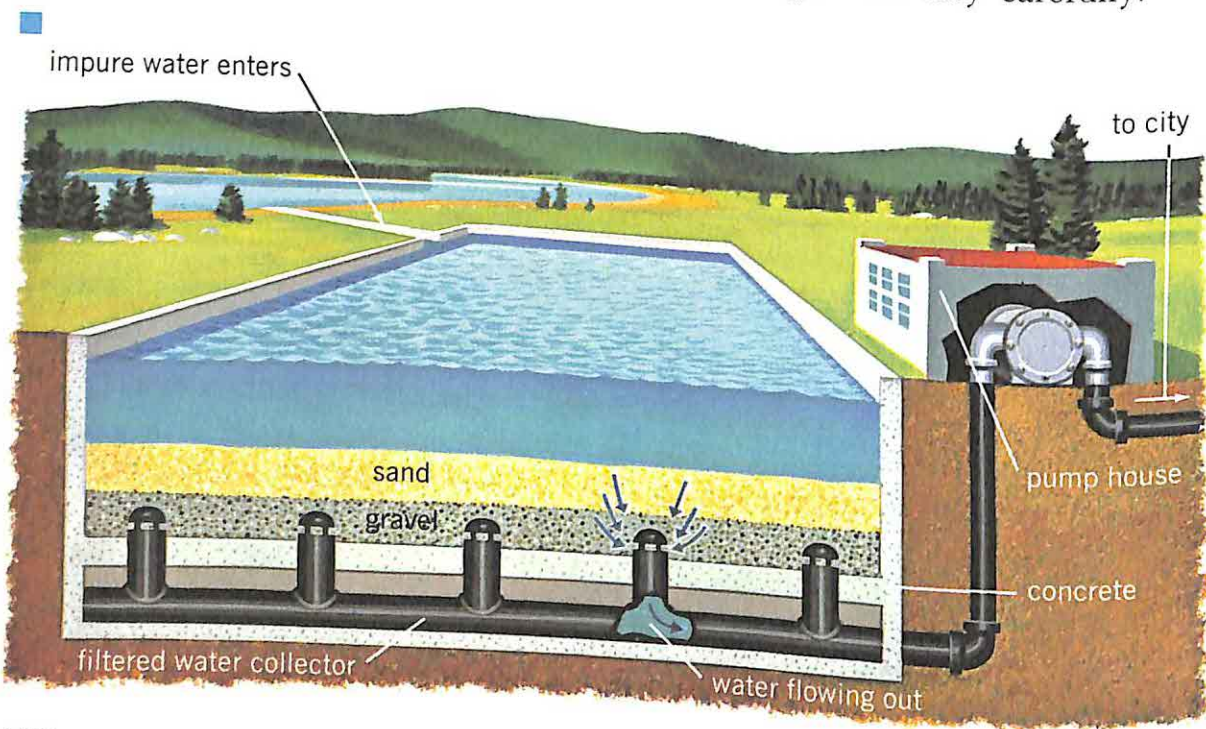
Water can be made safe to drink by boiling it for ten minutes. Of course, you could boil all your drinking water; but would everyone in a city do it? Is there another way to rid drinking water of harmful microorganisms?

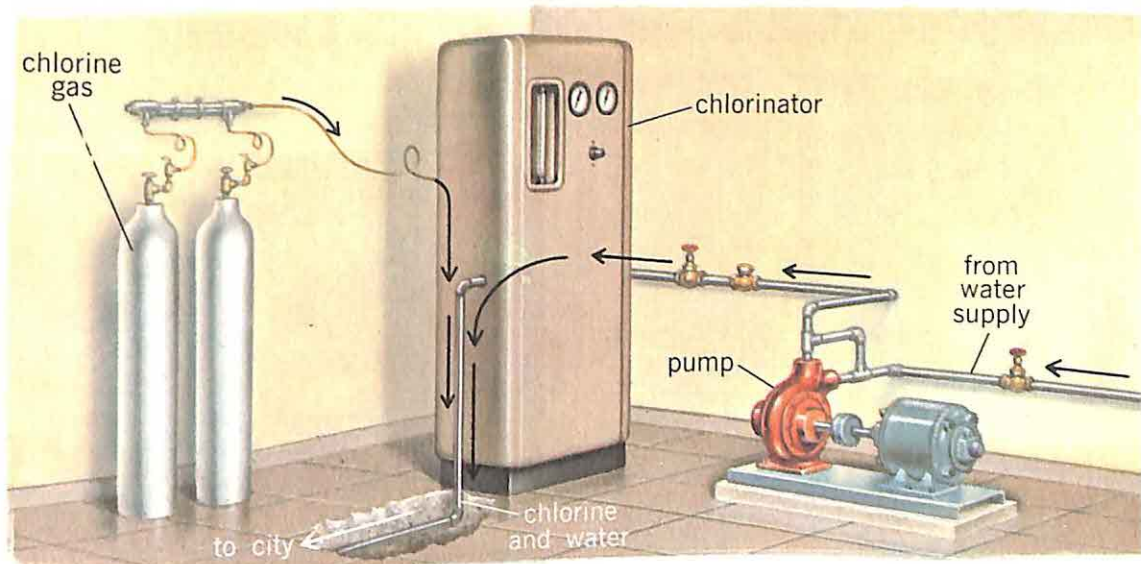
There are several ways to make water fit to drink. One method that helps to remove germs is called **filtration** (fil-trā'shən). In many cities the water flows through a filtering plant before it gets to the faucet. In the filtering plant the water passes through layers of sand and gravel. As the picture shows, much of the dirt in the water does not pass through. ■ The particles are too large to go through the layers of fine sand. Since bacteria frequently cling to particles of dirt, many of them do not pass through the filter either. They remain behind with the particles of mud or dirt.

Purifying Water for a Big City

A filter can remove many, but not all, of the microorganisms from the water supply. Some smaller bacteria and viruses pass right through. What can be done to stop them from getting through the filter and into your drinking water?

The bacteria can be killed by some substances. In many places a chemical is added to the water. This may be chlorine gas, which is added in small amounts. Chlorine kills bacteria and other microorganisms. In large amounts, chlorine gas is poisonous to people; however, the small quantity needed to kill most microorganisms is harmless to us. The picture shows the chlorination apparatus used for purifying water. The gas is added as the water flows past the gas jet in the pipe. ● The amount of chlorine used is regulated very carefully.





Sometimes other substances, such as sodium hypochlorite (sō'dē·əm hī'pə·klôr'it), are used to purify water, instead of chlorine gas. Substances, such as chlorine and sodium hypochlorite, can make the water a poor place for bacteria to live. See this for yourself by doing the investigation on the next page.

Safe Drinking Water

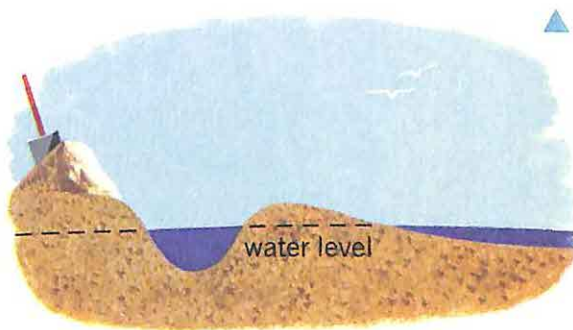
Your glass of water starts in the clouds. It falls as rain and is gathered in the **watershed**. A watershed includes all the streams that run into a lake or reservoir. Your glass of water finds its way into the reservoir. Sooner or later, most of the dirt settles and the water is clear. If the water is not clear, it may be filtered in order to rid it of soil particles and some bacteria. Clear water, however, may *not* be completely free from bacteria; so it must be treated with substances, such as chlorine, to rid it of

harmful bacteria. The glass of water you finally get is fit to drink.

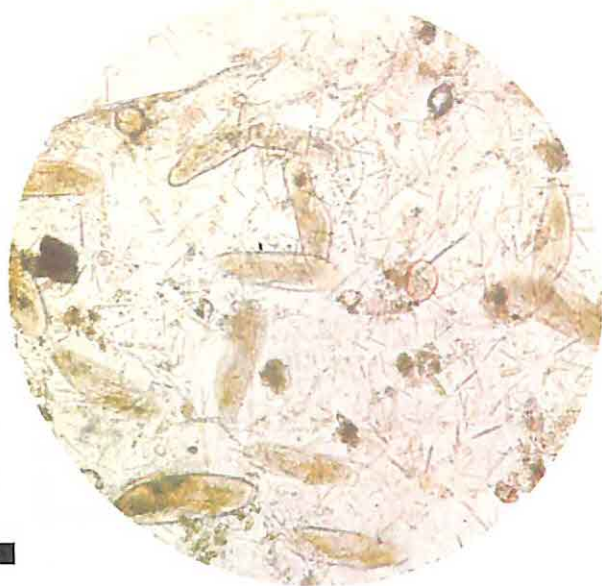
Water on a Farm

In the city, the turn of a faucet brings you water. The water is pumped in from a reservoir. On a farm, the turn of a faucet brings you water, but the water is often pumped into the house from a well. A well is really a kind of reservoir under the ground. Where does the water in a well come from? How does it get into the well?

Have you ever dug a hole in the sand near the seashore? Or in the soil near the shore of a lake? Soon the hole fills with water. ▲

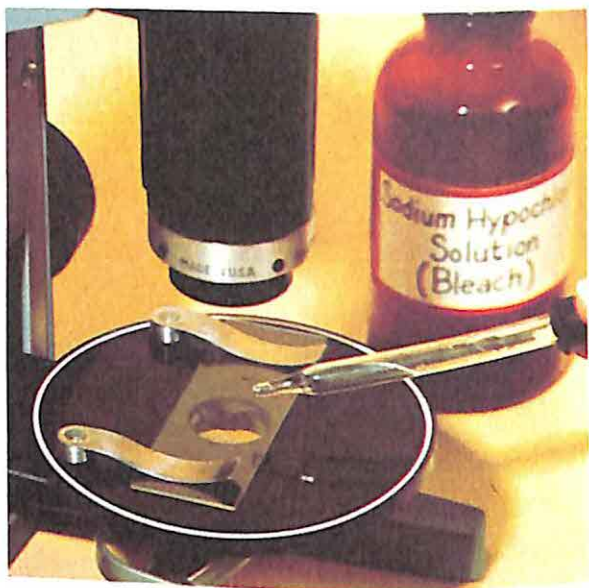


AN INVESTIGATION into Purifying Water with Chemicals



Needed: a microscope; a culture of some microorganisms (see below); some chlorine bleach (sodium hypochlorite); medicine droppers; and microscope slides. **WARNING: BLEACH IS A POISON. KEEP IT AWAY FROM YOUR MOUTH AND SKIN.**

First, prepare a culture of microorganisms. Obtain several pint jars of pond water, each from a different place. Crumble a piece of yolk (about the size of a pea) from a hard-boiled egg into each of the jars of pond water. Keep the jars away from the sun, but keep them in a warm (but not hot) place. After a few days or a week or two, the culture will probably swarm with tiny bacteria and other microorganisms. Use the culture for your investigation.



Examine several samples of the culture under the microscope until you find one containing a large number of living microorganisms. ■ As you watch them moving under the microscope, add a drop of liquid bleach to the water on the slide. ● How long does it take the bleach (sodium hypochlorite) to kill all the organisms you see?

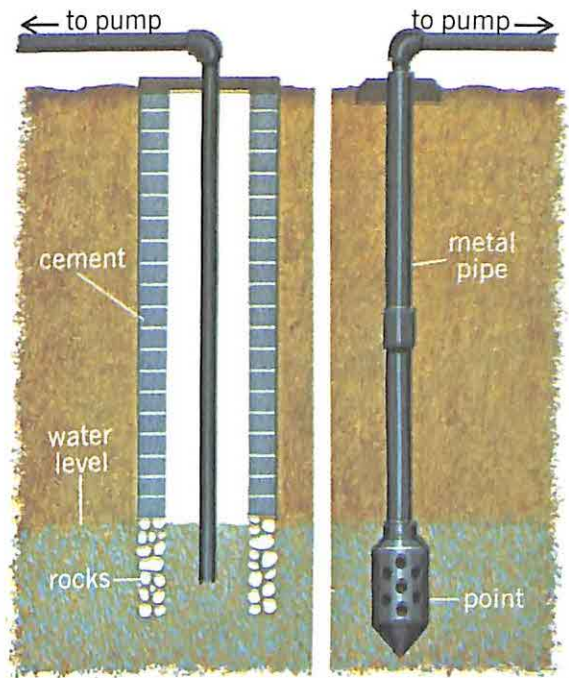
Investigate further to find out how much bleach is really necessary to kill the bacteria (or other organisms) in a drop of water.

Additional Investigation: Perhaps you have been on a hike. Did you get water for drinking from streams or mountain lakes? Today hike leaders carry Hala-zone pills, which are dissolved in the water before it is used. Investigate to find out how effective they are.

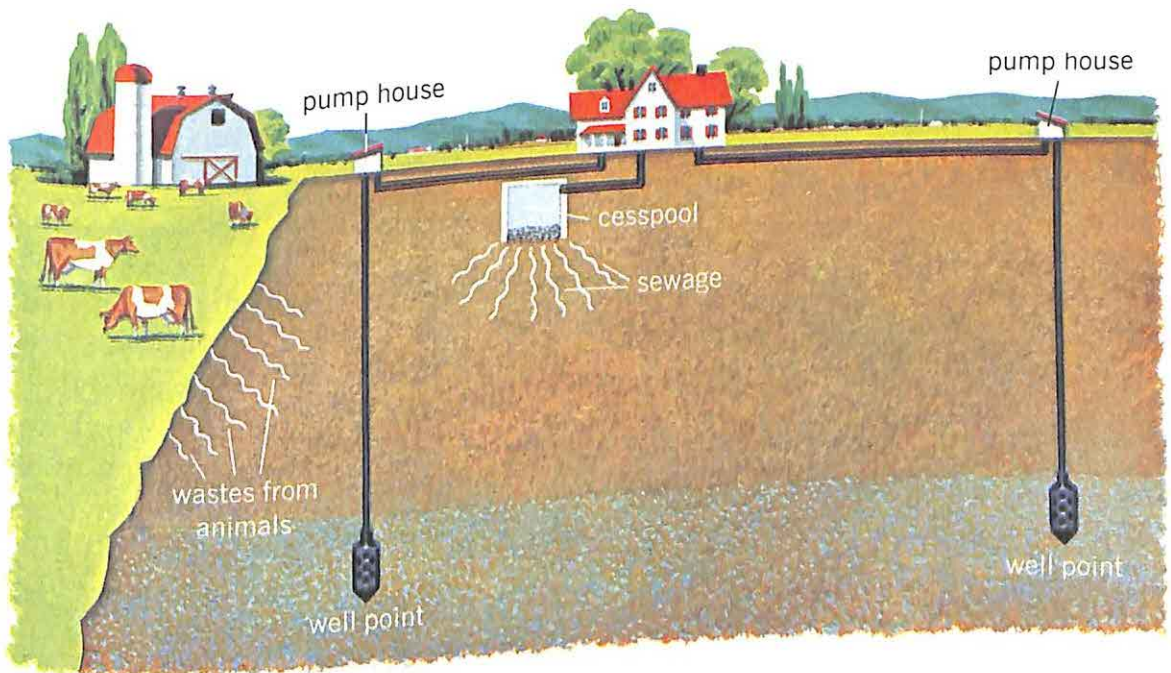
On a farm, a well may be dug where the ground has water in it. The well may be lined with rocks or concrete. ■ Some modern wells are simply a long pipe connected to a point that is forced into the ground, as shown. ■ To get into the well, the water must soak through the soil; thus, the water is filtered naturally by the soil. This filtering is often all that is needed to remove small particles and to keep out bacteria and other impurities.

It is important that the well be dug far from a barn or pasture. Animal wastes, garbage, and sewage are fine places for bacteria to grow; but they make the water unfit to drink. Which farm well shown in the illustration is in the best location? ●

When there is not enough water near the surface, a well is driven deep into the layers of rock in order to get



water. Wells driven through porous rock found deep in the ground usually supply water that is safe to use. By the time the water has filtered through rock to such a depth, most of the impurities have been removed.



If the water is not clear, if it is even a bit cloudy, it is best to boil it. Boiling for ten minutes will kill most bacteria. Well water must be tested often for bacteria.

When necessary, well water can be chlorinated by using a small device for adding chlorine gas to the water as it comes from a farm well. Chlorine is a purifier.

Health—A Personal Concern

Keeping well depends a great deal on *you* and *your family*. Ask yourself these questions. If your answer is “yes” to each of them, you are helping to keep dangerous bacteria out of your body and away from your friends.

1. Do I wash my hands before every meal?
2. Do I bathe regularly to keep my body clean?
3. Do I brush my teeth at least after breakfast and after dinner?
4. Do I keep my nails cut and clean?
5. Do I wash my hair at least once a week?
6. Do I always wash my hands after going to the bathroom?
7. Do I get proper care for cuts and bruises?
8. Do I show my teacher or parents a cut that is bleeding?
9. If I have a cold, do I stay away from other people until the cold is under control?
10. Do I stay away from people who have colds or other contagious (kən-tā'jəs) diseases?

You should answer “yes” to all the questions and know the reasons why. If you said “no” to any question, plan to practice doing that one thing until you do it almost without thinking.

Up to now, your health has been the concern of your parents. They have planned your diet, attended to your aches and pains, and been concerned with your growth. They are the ones who have seen that you had regular medical and dental checkups. Your school, too, has been interested in your health. Schools furnish many services, such as a visiting nurse, dentist, or doctor.

Soon your health will be your own responsibility. You must be ready to take over as an adult. You should do everything possible to keep yourself in the finest health. The human body is a marvelous machine. Its care and upkeep are not difficult—if you know what you are doing. Be sure you do.

Your Government Helps

In your community, much is being done to keep you well. You are required by law to be vaccinated against many diseases. You will not get smallpox or diphtheria, and the chances are very good that you will not get polio.

Water and food supplies are inspected. Laws requiring inspection reduce the chances that impure food or water will ever get to you.

Find out more about how your health is protected by doing the investigation on the opposite page.

AN INVESTIGATION into Keeping Water and Food Free from Bacteria

Needed: you and your imagination

This is a **research** problem. Research is, in a way, another term for investigating.

Research can be carried on in many places. It may take place in the library. It may take place in the laboratory or in the field. It may take place when you talk to an expert.

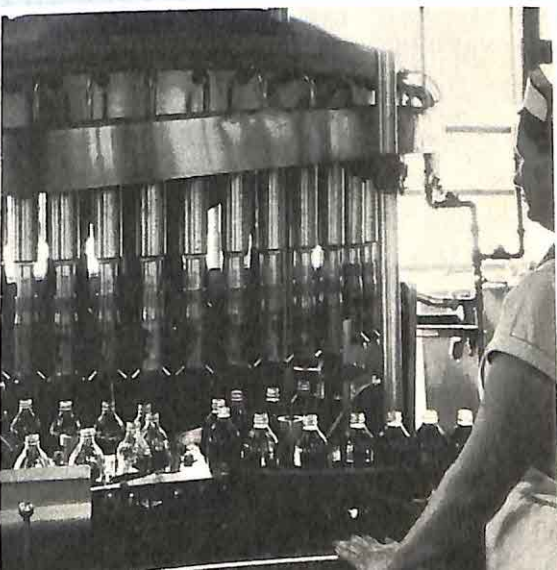
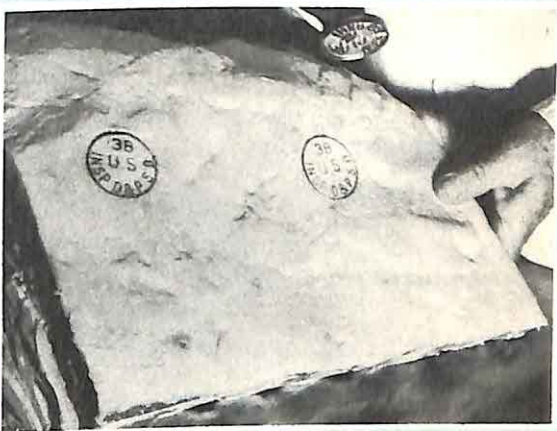
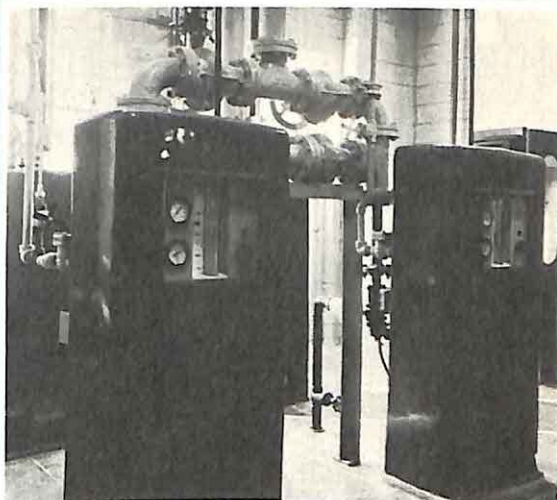
Wherever research is taking place, an attempt is being made to find out something.

Through research, try to find the answers to the four questions below. Where will you go for your research? to the library? to the laboratory? to an expert? Here are the questions:

- a. How is water purified in your village, town, or city? ■
- b. How is milk freed from most harmful (called **pathogenic**) bacteria, mainly those of typhoid and tuberculosis?
- c. What does the purple stamp on meat (Inspected U.S.) mean? ●
- d. How is bottled food kept free from bacteria? ▲

Notice that the four questions have to do with the technology of controlling disease.

Write the results of your research in a notebook. Your teacher may want you to report your results to the class.



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. When on a hike it is easiest to purify water by adding
 - a. chlorine
 - b. Halazone pills
2. Dirt and mud can be removed from water by
 - a. filtration
 - b. chlorination
3. Impure milk or water is known to be a carrier of
 - a. polio
 - b. typhoid

B. Score yourself on the questions asked on page 136. Give yourself a mark of 2 for any question you answer "All the time." A mark of 1 goes for any question you answer "Some of the time." Give yourself a mark of zero for any answer like "None of the time" or "Never."

What is your score? Did you score below 20? If so, which health practice needs correcting?

**USING WHAT
YOU KNOW**

1. With the help of your mother or father, check your medicine cabinet. Is everything labeled? Are all antiseptics and drugs out of the reach of young children?
2. How does a deep well help in the maintenance of a safe water supply?

ON YOUR OWN

What is the source of your water supply? If you live in a city, find the area where the source is and where the reservoirs are. Find out what method is used to protect your water supply.

This too is a kind of research problem—a way of investigating. Research may take place in the laboratory, in the library, or in the field. The scientist uses many approaches in seeking the answers to his questions. Probably the most important skill that he uses is that of careful observation; but accurate measurements may be considered equally important.



7. The Main Concept: Controlling the Environment

All living things depend on their environment for food, water, and shelter. ■ Without the sun's energy, green plants do not make food and cannot live; without green plants, animals cannot live. They depend on green plants not only for food but also for oxygen.

We depend on our environment; but the environment is not always friendly. The tiger feeds on the deer. Some snakes feed on mice. Animals feed on each other, as well as on plants. Some animals and plants are dangerous to humans, too.

Some bacteria would kill us if we let them; others would make us sick. Over the years there have been many diseases which were caused by microorganisms. Such diseases have killed many men and there are many other diseases that still do.

Before the microscope was invented, man did not know about microorganisms. A tool had to be invented before he could discover the cause of many diseases. Without the microscope we could not have known about microorganisms, the invisible enemies against which we must always be on guard. These invisible enemies killed many people and made many others very ill.

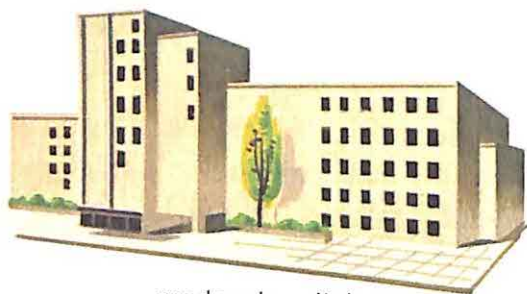
For example, the Black Death, a disease caused by bacteria, killed one-fourth of all the people in Europe about 600 years ago. The disease is caused by a specific kind of bacterium, but the concept that bacteria and other microorganisms cause disease was not known 600 years ago.

Tuberculosis killed many and still does; cholera and typhoid were common too. Before 1900, smallpox was a disease that caused many deaths. Today, smallpox is almost unknown; an epidemic unheard of.

■ CONTROLLING THE ENVIRONMENT



water-purifying plant



modern hospital



refrigerated truck



modern supermarket

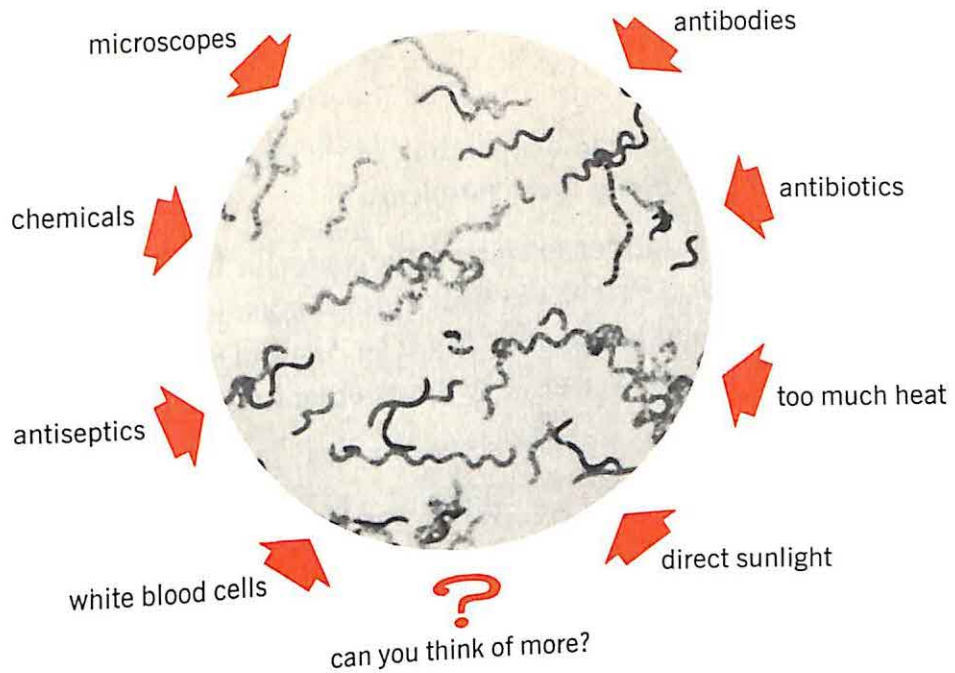
Even today, in the warmer climates of the world, malaria, caused by a microscopic protozoan, kills many people—too many.

Through science and technology, however, man has learned to control, and even to wipe out, many diseases. He has learned to do a very important thing, to control and change his environment. ■ He has learned also to change the environment of some microorganisms, so they cannot survive. Now man purifies water to kill the microorganisms in it; the government inspects meat and fish to get rid of any infected food; people are vaccinated against smallpox, diphtheria, or polio.

Man controls his environment. He has learned to control it in many ways. He makes laws, for instance. There are laws against stealing. There are safety laws. Drivers obey safety laws when they drive within speed limits or stop at red lights. There are also laws which apply to contagious diseases. Persons who have diseases that spread easily to other people must be isolated—by law. They are placed under **quarantine**. Quarantine thus protects other people's lives.

In addition to controlling his own environment, man tries to control other living things which could destroy him. What must he know in order to control the microorganisms which could kill us? Man had first to discover what germs are and how and where to find them. To do this, he needed many new inventions: the

● THESE FACTORS MAKE THE ENVIRONMENT
UNSAFE FOR DISEASE GERMS



microscope, stains to color the bacteria so that they might be examined, ways of growing bacteria, ways of collecting them. To get rid of the bacteria, for instance, he needed to know how to produce antiseptics, to know how the body produces antibodies, and to know how molds produce antibiotics.

Scientists learned to control the environment so that it is not safe for many organisms that cause disease, but is safe for us. ● This is one aim of medical research. Medical-research scientists seek the causes of disease. Just as Louis Pasteur did, or as Sir Alexander Fleming and Jonas Salk did, scientists learn to control certain organisms in our environment, particularly the ones that cause disease. In so doing they prevent disease.

Animals and plants live together in their environment. Man lives in the environment as well. He breathes the air and drinks the water. He feeds on plants and animals; and, in turn, certain organisms (like bacteria and viruses) feed on him—if they can. By learning how to control such organisms, man controls his environment—and in so doing, *improves* and *lengthens* his life.

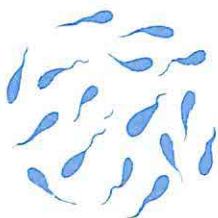
Man, as a scientist, has learned to control his environment mainly by investigation. By controlling the variables in his experiments, his conclusions are more accurate. Accurate observation and measurement are two of the most important skills that man, as a scientist, has acquired. But that is also true in all walks of life—not just in science.

Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts of this unit by doing these problems.

1. A farmer examined the water in his well and found it cloudy. He sent the water for examination to the Health Department in a nearby city. The Health Department found that the water was full of microorganisms like those shown. ■



- What was in the water?
- Are these microorganisms dangerous? Why?
- What do you suggest could be done?
- How can well water be purified?

2. In 1900, diphtheria and typhoid were common diseases. Now they occur very rarely in the United States. What reasons can you give for this?

3. What services does the government provide to protect our health and welfare?

4. What reasons would you give for doing the following:

- A group of hikers boils the water from a stream before they drink it.

- A housewife puts meat in the refrigerator.

- Water entering a reservoir goes through a filtration plant.

- Water entering a big city from a reservoir is chlorinated.

5. An antibiotic can be taken (or injected) into the body; so can an antibody. An antiseptic can be used externally but is poisonous when taken into the body. Why?

6. Use each of these key words or terms in a sentence.

antiseptic

antibody

antibiotic

immunity

coccus

bacillus

covering cell

hypothesis

control experiment

spirillum

virus

vaccine

enzyme

spore

bacterium

white blood cell

experimental design

microorganism

QUICK TEST

Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this unit.

1. One of the following is *not* a bacterium. Which is it?
 - a. coccus
 - b. bacillus
 - c. virus
 - d. spirillum
2. Certain iodine products are used as
 - a. antiseptics
 - b. antibodies
 - c. antibiotics
 - d. enzymes
3. Streptomycin is an
 - a. antiseptic
 - b. antibody
 - c. antibiotic
 - d. enzyme
4. Diastase is an
 - a. antiseptic
 - b. antibody
 - c. antibiotic
 - d. enzyme
5. A polio vaccine was developed by Jonas Salk. In addition, another vaccine for polio was developed by
 - a. Selman Waksman
 - b. Albert Sabin
 - c. Alexander Fleming
 - d. Howard Florey and Ernst Chain

FOR YOUR READING

1. *The Wonderful World of Medicine*, by Ritchie Calder, published by Doubleday, Garden City, 1958.

This book describes the story of how man began to control the microorganisms in his environment. It describes the history of medicine from the witch doctor to modern times. Many colored photographs illustrate this book.

2. *Miracle Drugs and the New Age of Medicine*, by Fred Reinfeld, published by Sterling, New York, 1962.

This book tells in detail the story of the discovery and production of the modern "wonder drugs."

3. *The Story of Microbes*, by Albert Schatz and Sarah Riedman, published by Harper and Row, New York, 1952.

This interesting book tells the ways in which bacteria are used in making such products as cheese and sauerkraut.

4. *The Microscope, and How to Use It*, by Georg Stehli, published by Sterling, New York, 1961.

This is a book for beginners; it is especially good for those who own a microscope. If you are interested in using a microscope, you will want to learn many of the technical terms used.

ON YOUR OWN

1. Yeasts are fungi. Recall that fungi are plants without chlorophyll. Bacteria are also plants without chlorophyll. In many ways, the yeast cell works like the bacterial cell. The working of a cell is called its metabolism (me-tab'ə-liz'əm). The way a cell makes use of its food is part of its metabolism.

For instance, when your cells use a food they combine it with oxygen to yield energy. Thus, if your cells were to use sugar and oxygen, they would combine them to form water and carbon dioxide.

Yeast cells use sugar, too. What do yeast cells produce when they use sugar? Do they produce carbon dioxide, just as your cells do? As bacterial cells do? Or do they produce oxygen (in the presence of light) as green plant cells do?

Yeast cells can be grown in a solution of sugar. Add about a teaspoon of sugar to half a glass of water. Add to the sugar solution $\frac{1}{2}$ teaspoon of powdered yeast. How can you collect the gas which is given off? How can you find out whether it

is carbon dioxide? It is easy to test for carbon dioxide in the air you breathe out; but it is not so easy to do this for yeast.

Test your ability to use your ideas to find or to invent a tool.

2. Do some research in the library about the development of an antibiotic to combat the staphylococcus—a bacterium which is very resistant to most antibiotics.

PROJECTS

1. Grow a mold garden.

On a paper plate put some scraps of food from the table—a piece of orange, apple, white bread, whole wheat bread, and a grape, if you can. You may want to use foods other than those mentioned.

Leave scraps of food on the plate, open to the air over night. Spores of different molds may be present in the air.

Cover the paper plate with a piece of plastic. This will keep the moisture in. Examine the plate each day.

How many different kinds of molds have you grown? Compare yours with those grown by your classmates.

If you have a microscope examine each sample in a drop of water. To do this, pick up a bit of mold with a toothpick. Put the bit of mold in a drop of water on a slide and cover it with a cover glass. Does it look like one of those shown in the illustration? ■

2. Plan an investigation to determine whether molds grow better on carbohydrate foods (starches and sugars) than they do on protein foods (meats, cheeses, etc.). Try to control the different variables.



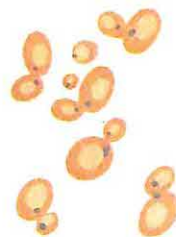
penicillium



aspergillus



bread mold



yeast

A Concept of Interdependence:

A New View

Everyone learns; indeed, everyone must learn in one way or another. The *way* the scientist learns is one of the great designs of man. He is constantly searching for a better understanding of the objects and events in the world around him. Most of his searching takes place in libraries, laboratories, and research centers. He is uncovering a vast reserve of new knowledge that was formerly out of reach. Currently, this new knowledge is being published at the rate of 60 million pages a year. At this rate, it would take a fast-reading scientist eight hours a day (with no time off for lunch), until the year 3363, to finish reading a year's discovery of new knowledge.

Look around you. In this modern age it is hard to find one substance that has not been affected by the knowledge that scientists have discovered; but above and beyond uncovering new knowledge, *what are scientists really searching for?* Let us use a particular example to find one answer to that question.

When you go into the woods or into any environment where you can observe living things, you will find a vast number of plants and animals. In just one environment you may find an odd assortment of such things as dogs and daisies, rabbits and roses, frogs and salamanders, many kinds of fishes, mosses, ferns, and seed plants.

What a vast number of plants and animals there are! The number is so vast that one wonders how anyone can learn all about them. Fortunately, there exists among all these different living things certain likenesses or relationships; but you may ask why they are important. Well, let's see if we can find out.

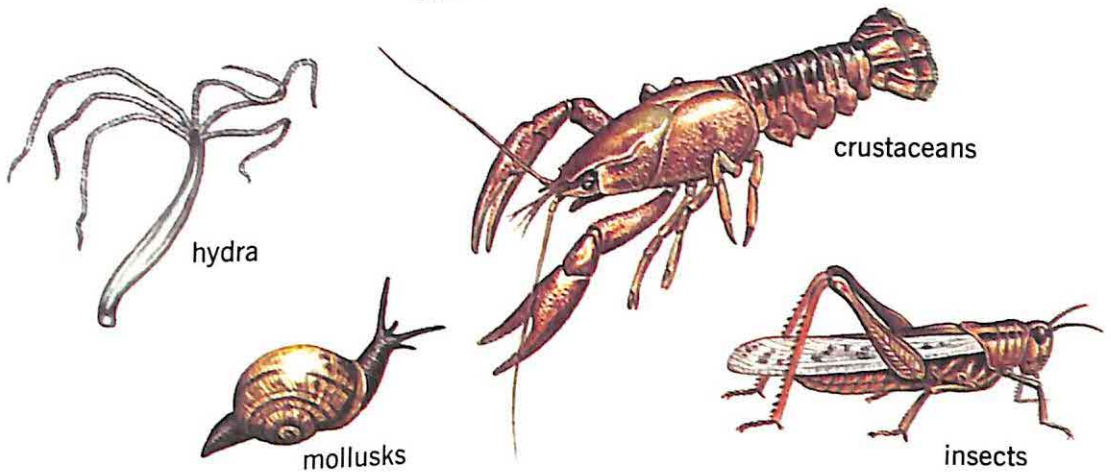
Look at the chart on the opposite page. It shows one way that scientists group, or **classify**, animals. Animals in certain groups seem to be closely related to each other. ■ Mammals are related. They have much the same structure. The muscles, bones, and nerves of a dog are much like those of a cat, an elephant, a horse, or a tiger. They all have hair. If we were to look at the skeletons of each of these animals (all mammals), we would find that their skeletons are similar.

Birds are related to each other. They all have feathers. In addition to being related to each other, they have a structure which is similar to that of the amphibians and reptiles. The fishes too, as well as the mammals, have something in common with the birds, amphibians, and reptiles. They are all **vertebrate** animals. Their backbone is made up of sections called **vertebrae**.

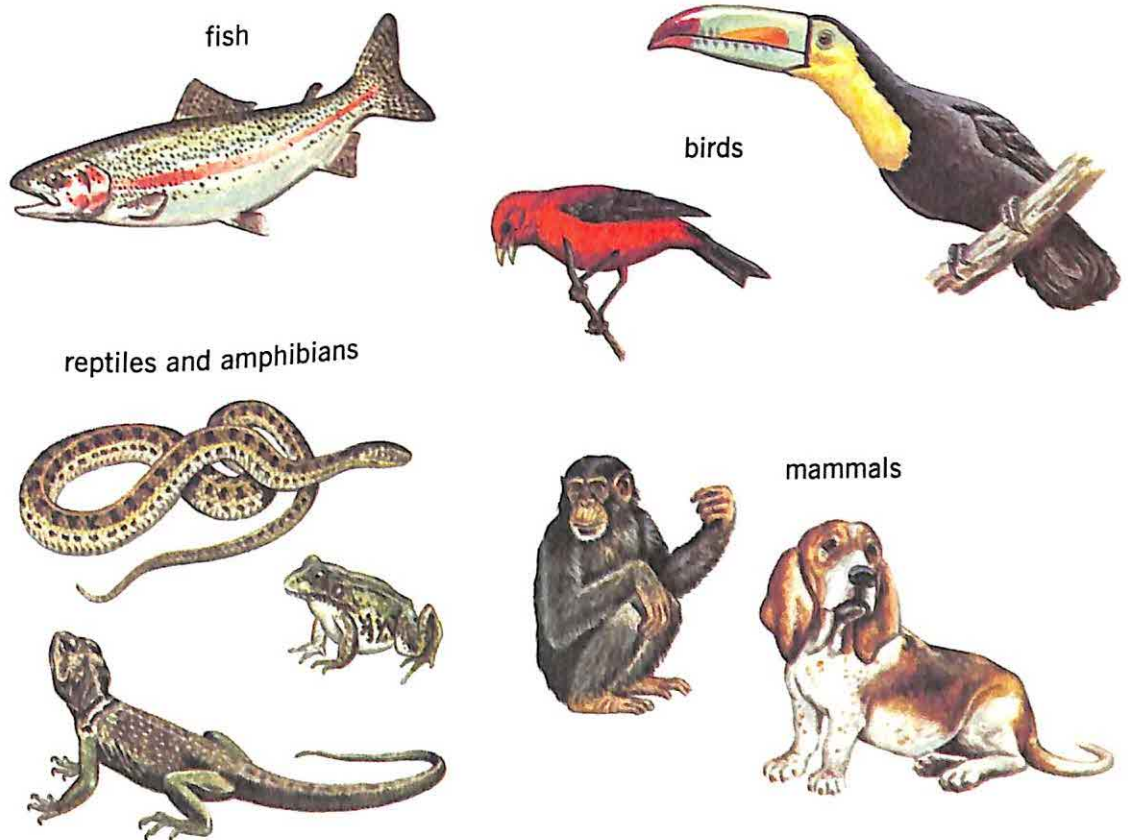
Invertebrates are animals without backbones. The number of invertebrates is vast and includes such ani-

■ CLASSIFICATION OF SOME ANIMALS

invertebrates
(animals without backbones)

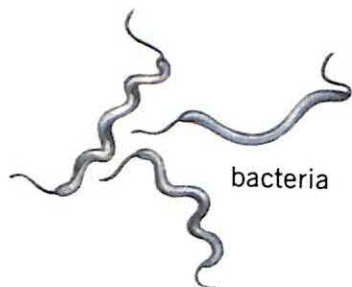


vertebrates
(animals with backbones)



■ CLASSIFICATION OF SOME PLANTS

nonvascular
(without "water tubes")



bacteria



bread mold



moss

vascular
(with "water tubes")

spore-bearing



fern

seed-bearing
(flowering)



apple



tulip



pine

mals as worms, insects, and shellfish. Can likenesses also be found among invertebrates?

Look at the chart which shows one way that scientists classify plants. ■ Flowering plants seem much like each other; they have the same structure. If you look inside their stems and examine their flowers, you will find that flowering plants are related. Mosses, ferns, and molds are different from flowering plants. Do they have likenesses to each other? Careful examination will show that they do.

Plants and animals, then, can be grouped, or classified, according to their likenesses or relationships. Understanding their likenesses makes their differences easier to understand. In addition then to uncovering new knowledge, the scientist is constantly searching for relationships, the *concepts of science*.

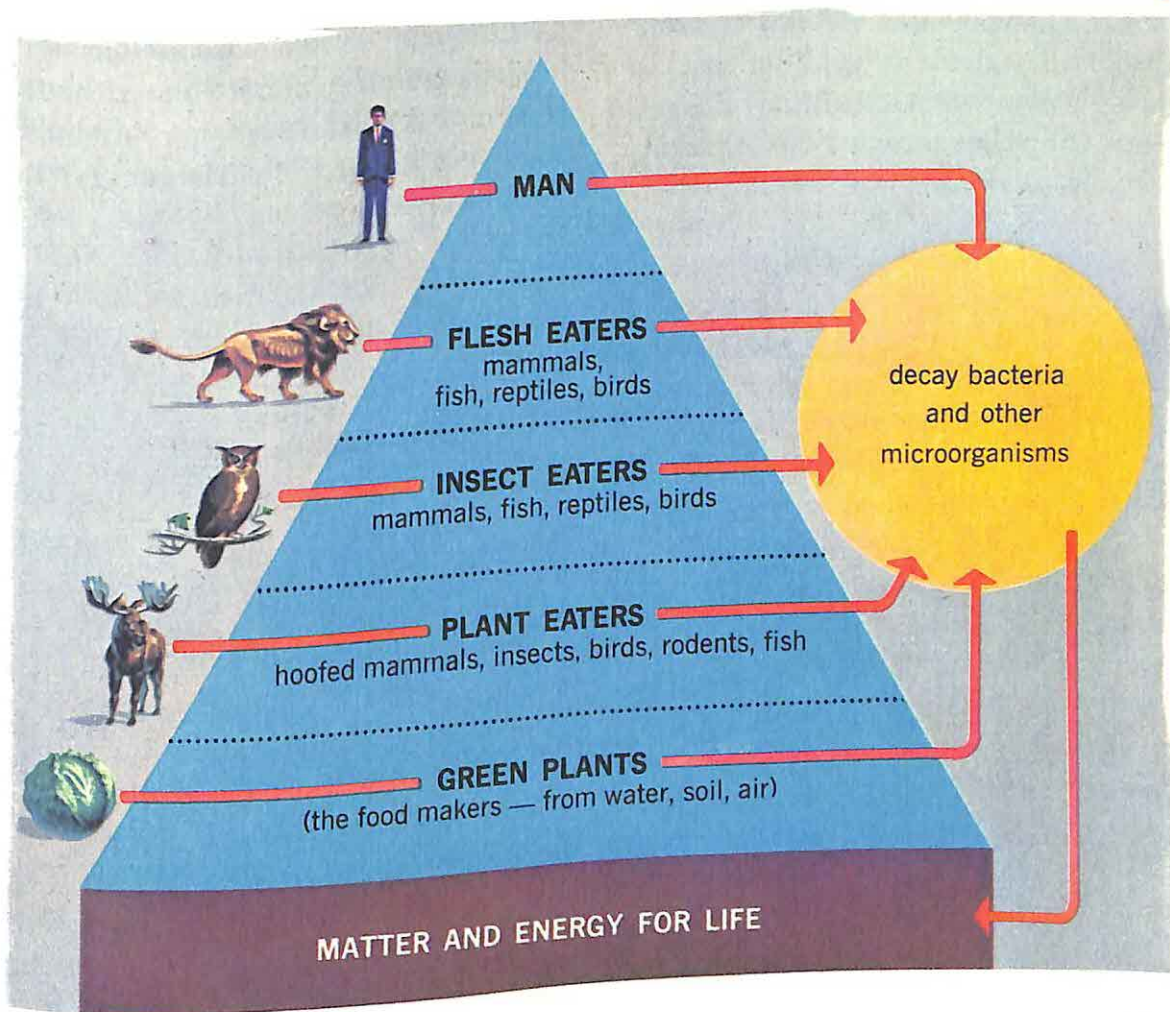
Now focus your attention on one of the major concepts in this section: *Interdependence*. Everywhere you look, you can observe that living things are dependent on their environment.

Cattle cannot live without grass. Grasses are other living organisms. They depend on and use light energy from the sun, 93,000,000 miles away, to make their food. Both cattle and grasses depend on their environment for the matter and energy to keep them alive.

This is true for other living things as well. The robin feeds on the earthworm; the earthworm feeds on decayed leaves that are found in the soil. The decayed leaves were once the green leaves of the plants which got

their energy from the sun. A mouse feeds on wheat; the wheat got its energy from the sun. In turn, the mouse may become food for a cat or a hawk. Each animal obtains matter and energy from its food. The carbon in food combines with oxygen from the air that an animal breathes in. The animal breathes out carbon dioxide.

There even seems to be a kind of order in the feeding habits of animals, as shown in the diagram of the pyramid of life. ● It is another way of showing how living things depend



carbon dioxide + water

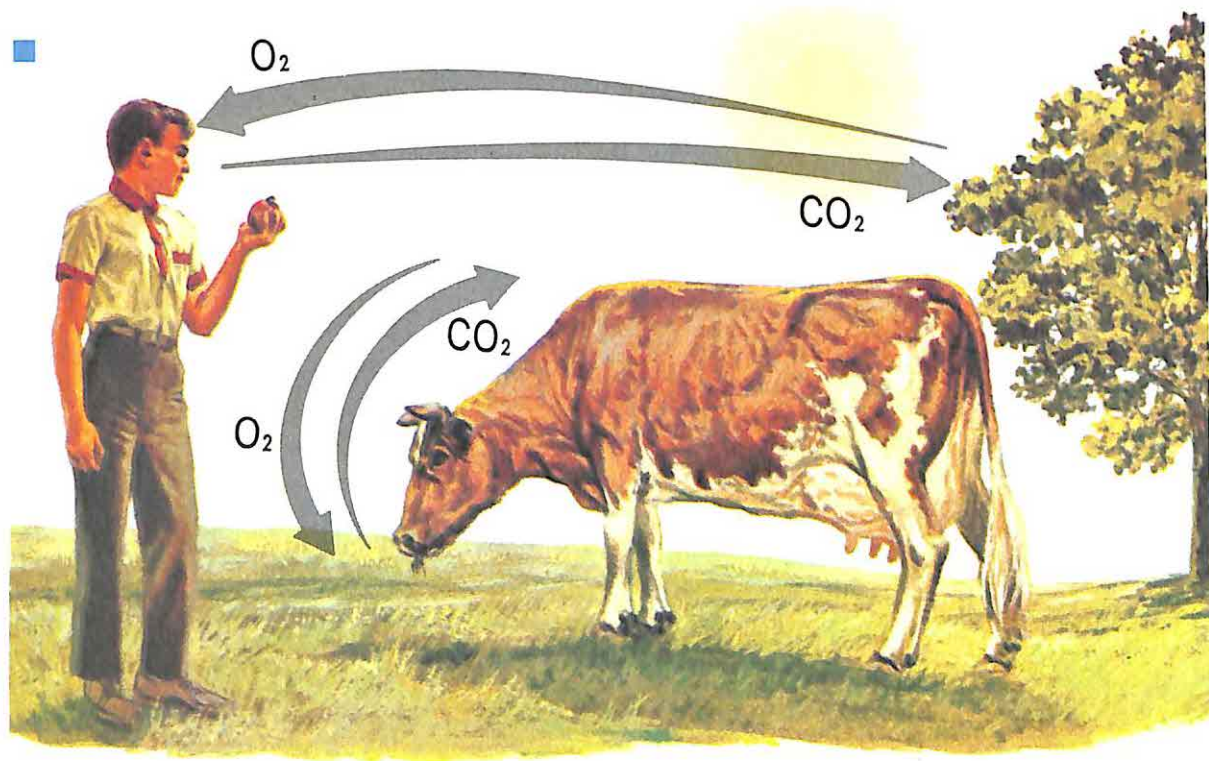
glucose + oxygen

upon one another. The animals near the top of the pyramid get most of their food by eating other living things which are lower down on the pyramid. This is not always true. Can you think of some exceptions?

A scientist once made the statement: "Every living thing is useful because it provides food for some other living thing." Can you explain what the scientist meant by that statement? Do you think he was correct? Does this statement apply to man as well? Under what conditions do you think it applies to man? Give reasons for your answer.

Animals get food and oxygen from plants. What do plants get from animals? They get carbon dioxide gas, which supplies some of the matter needed by green plants for the process of foodmaking. ■ In the green plant a chemical reaction takes place to produce glucose, a kind of sugar. In the reaction, oxygen is given off. A word equation for the reaction is shown above. ●

Plants cannot live without carbon dioxide; animals cannot live without oxygen. Neither plants nor animals can live without the sun's energy; it sustains all life.



This brief survey about plants and animals points out one great concept: *Plants and animals are interdependent with one another and with their environment.* Both plants and animals get the matter and energy for growth *from* their environment. As plants die, they return matter and energy *to* their environment. So do animals. Plants and animals are constantly exchanging materials.

Man too depends on his environment and on plants and animals. If you visit a supermarket, you will see how dependent you are on plants and animals for food. As a matter of fact, you don't even need to go to the supermarket to find out. Just ask yourself this question: How many different kinds of plants and animals did I eat today? What products did I use that came from plants or animals?

Besides using plants and animals for food, man uses the hides of animals for shoes, the wood from trees to build houses, the fiber from the cotton plant to make his shirts, and the wool from sheep to make his suits and coats. Even the synthetic fibers that man uses are made from matter found in the environment.

Man is interdependent with his environment but that is not the whole story. Modern man can do much more; he uses science and technology to *change* his environment. Because of his brain man can investigate his environment and change it in such a way that men who lived 10,000 years ago would not recognize it.

Man, as a scientist, has learned to *observe* and to *investigate* his environment. He searches for relationships which help him to *understand* his environment. From the relationships he develops concepts which enable him to *change* his environment. He is always looking for new and better ideas to create new and better products.

For example, the concept that matter is made up of particles provides the basis for rearranging the particles (the atoms and molecules) to form new substances. Man takes from his environment

- iron ore and makes iron;
- iron and makes steel;
- coal, air, and water, and makes nylon.

What concepts does man use when he

- makes antibiotics to combat disease?
- makes rockets to conquer space?
- makes refrigerators, furnaces, and houses to combat weather?
- builds schools and writes books so that what he has learned is available to others?

Man is the dominant organism on the earth. He is learning how important the environment is to him. He is learning also, even if slowly, to use it wisely.

Science is a part of your world. Just as you have learned to use words and numbers, you are now learning to use the concepts and tools of science. Will you use them wisely?

CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

(Text pages 152–93)

UNIT CONCEPT

The amount of energy gotten out of a machine does not exceed the energy put into it.

A Preview of the Concepts

Unit Four

MACHINES IN ACTION

The pupils investigate each of the common machines that man has invented and derive the concepts on which they operate. They discover that while machines make work easier by multiplying the forces applied, there is no increase in the work done. Energy input can never be more than the energy output (work), which includes energy transformed to overcome resistance (friction).

A VIEW OF THE UNIT

Archimedes, the Greek mathematician and inventor, once said, "Give me a place to stand and I will lift the world." He may have been talking about a long bar, a fulcrum, and the force he could exert by his own effort. It would have had to be a very long bar indeed! Whatever machine he had in mind, he understood the concept of multiplying the force of man's muscles. As Astronaut White discovered in June of 1965, a small push in space on the heavy Gemini capsule moved it easily. On earth, friction of the atmosphere and of the contact surfaces of the capsule and the ground would have made any effort to move the capsule unproductive. Perhaps Archimedes was not so far wrong after all, for Astronaut White surely did work in the scientific sense.

Scientists long ago understood many of the concepts of simple machines. Technologists have been inventing improved machines. They have been concerned with effort, load (or resistance), distance, and speed. Our modern economic society requires a vast amount of work to be done in a short time and with the least sacrifice in distance. The production of machines that multiply effort, reduce resistance, and increase speed and distance are the concern of the technologist and engineer. The relationships that explain the concept of work are the concern of the scientist. This unit develops these relationships from which the pupils themselves can formulate concepts and draw inferences from them.

In Section 1, the pupils investigate the most common attributes of simple machines. In Sections 2–4, they investigate each simple machine individually and find that all do work in the same way—by moving an object through a distance. These machines may change the direction in

which an effort force is applied, may multiply the force applied, or multiply speed. The relationships are derived by the use of simple arithmetic in investigational observations.

While the term *mechanical advantage* is not used in the pupils' text (you may wish to introduce it), the pupils discover that effort applied to do work is multiplied by the use of machines. (No work is saved!) If half the effort force is needed to do a given amount of work (mechanical advantage of 2), they see that a machine will move twice the load through a given distance with the same effort, or double the speed (distance covered) with twice the effort—disregarding frictional resistance, of course. Machines with a favorable mechanical advantage are often combined to multiply the mechanical advantages. For example, a wheel and axle with a mechanical advantage of 3 combined with a movable inclined plane, as in a meat grinder with a mechanical advantage of 6, affords a mechanical advantage of 18 in the compound machine. Again, the text does not develop this mathematical relationship, but a perceptive student may raise the questions.

In Section 5, pupils investigate the effect of frictional resistance on the work done and consider the question: Is friction ever a useful force? (Of course it is, because work is done in slowing the motion of objects as well as in moving them through a distance.) From their investigations, pupils now progress to the meaning of work in a scientific sense, deriving an equation (or a statement in words) that expresses the relationship mathematically; that is $\text{Work} = \text{Force} \times \text{Distance}$. This equation is also seen to express the relationship between the work (energy) put into a machine and the work got out. If either Force or Distance is 0, no useful work is done, no matter how tired a person gets or how heated a machine becomes. The energy is converted into other forms, but no work is done; no force is moving an object through a distance.

A word or two about *efficiency* and *power*. We have not attempted to develop these aspects of work. The concept of efficiency is a mathematical expression in percentage, a ratio between work input and work output. It is not necessary in understanding *how* machines work; only in understanding *how well* they work. *Power*, of course, is the rate of doing work. Pupils can understand that the use of machines permits the performance of the same amount of work in a shorter time, but the meaning physicists attach to power rests on mathematical computations. We have purposely limited the concepts to *energy*, *force*, and *work*, leaving *power* to a later year. To avoid confusion later, it is best not to refer to water power or electric power, but to energy from moving water or to energy from flowing electrons or to the force of water or the force of electricity.

Once again, in this unit, the pupils see that man has used concepts of science to invent tools to multiply the force, relatively feeble, of his muscles.

SUPPLEMENTARY AIDS

Names and addresses of distributors and suppliers of films and filmstrips are on page F-26. All films and filmstrips are in color. Several films are available with sound track, as indicated in the listing.

Films

Forces (14 min.), E.B.F. Demonstrates how a force can make an object move, deform objects, and can speed them up or slow them down. Three kinds of forces—magnetism, electricity, and gravity. (Intermediate)

What Is Uniform Motion? (14 min.), E.B.F. Defines uniform motion as constant speed or equal distances in equal times. Force starts motion; friction slows motion; gravity pulls object toward earth. (Intermediate)

Energy at Work (11 min.), E.B.F. Shows how energy has the ability to do work; can be changed from one form to another; can be stored (potential). Energy of objects in motion is kinetic energy. (Intermediate)

Filmstrips

The Pulley; The Lever; The Wheel and Axle; Inclined Plane, Wedge, and Screw; Wheels, Belts, and Gears. Five filmstrips on machines (each 11 min., with sound track), Cenco. The work done by each type of machine is pictured, its principle described and illustrated by example. Basic concepts of work and force are introduced. (Intermediate)

Work and Friction (38 frames), Jam Handy, 1964. Simple experiments show what scientists mean by work, force; how work is measured; meaning of friction and how to reduce friction. (Intermediate)

Inclined Planes at Work (38 frames), Jam Handy, 1964. Simple investigations show how simple machines make man's work easier and how the inclined plane makes it possible to do work with less force. Shows applications to industry. (Intermediate)

Levers at Work (38 frames), Jam Handy, 1964. Explains how a lever makes work easier and the purpose and best location of the fulcrum. Gives examples of the kinds of levers, according to position of fulcrum, and shows relationship between force and resistance and application of the lever to man's work. (Intermediate)

Pulleys at Work (38 frames), Jam Handy, 1964. Explains parts of a pulley system and how these systems help move objects; discusses kinds of pulley systems, such as fixed and movable pulleys, what each one does, and the relationship between the number of supporting cords and the force required to do a given amount of work. (Intermediate)

Wheels and Axles at Work (38 frames), Jam Handy, 1964. Explains how it is easier to move things more easily on wheels, the advantages of the wheel and axle, and the effect of a change in size of wheel or axle to the force needed. Application to everyday jobs. (Intermediate)

Screws and Wedges at Work (38 frames), Jam Handy, 1964. Describes a screw as an inclined plane wound around a cylinder, and shows how it works; what a wedge is and how it is used in doing work. (Intermediate)

The Work of the Wheel and Axle (44 frames, sound), S.V.E., 1965. Shows wheel and axle in common objects; demonstrates the mechanical advantage of simple machines and how to measure the work they do. (Intermediate)

The Work of the Lever (41 frames, sound), S.V.E., 1965. Defines a lever, and gives examples of the kinds according to the location of the fulcrum; shows how to determine the mechanical advantage and how to measure the amount of work done. (Intermediate)

The Work of the Pulley (49 frames, sound), S.V.E., 1965. Tells what a pulley is and how it works; the operation of fixed and movable pulleys and the block and tackle; shows the relation of a pulley to a wheel and axle and a lever; and how to measure in foot-pounds the work done. (Intermediate)

The Work of the Inclined Plane, Screw, and Wedge (44 frames, sound), S.V.E., 1965. Shows that although an inclined plane multiplies effort, we must put in as much work as we get out; how to measure the mechanical advantage. (Intermediate)

The Work of Gears (40 frames, sound), S.V.E., 1965. Shows how gears, belts, and chains transfer a force; how gears change direction in which a force acts and how they give a mechanical advantage. By using different sizes of gears we multiply force but lose speed or gain speed by reduction in force. (Intermediate)

Titles with an asterisk (*) are especially recommended. Addresses of the publishers are on page F-24.

All About Engines and Power by Sam and Beryl Epstein, Random House, 1962. Describes man's continuing search for more efficient methods of producing power. Includes material on the workings of gasoline and diesel engines, turbines and steam engines, rockets and jets, electric generators and nuclear reactors. The relation of scientists to inventors is apparent. (Average)

Atoms, Energy and Machines by Jack McCormick, Creative Educational Society, in cooperation with the American Museum of Natural History, New York, 1962. An informal introduction to physics and chemistry. Includes material on new developments as well as the basic topics. Many photographs and illustrations help to explain scientific discoveries and their application. (Advanced)

* *Energy* by Mitchell Wilson and the Editors of *Life*, Time, Inc., 1963. Valuable resource for information about energy in all its forms. A picture essay is included in each section. Scholarly treatment of the subject written in layman's language, with new and difficult terms defined in the narrative. (Advanced)

* *Machines* by Robert O'Brien and the Editors of *Life*, Time, Inc., 1964. Includes material on the five fundamental machines; weapons from slingshots to gunpowder; and household machines and how they work. A fascinating chapter, "The Promise and Problems of Automation," describes, among many other marvels, automation at the world's largest wiener factory. A picture essay is included in each section. (Advanced)

Science Reading Table

Simple Machines and How They Work by Elizabeth N. Sharp, Random House, 1959. Some easy investigations and many examples involving familiar objects and activities make simple machines easily identifiable. Clear diagrams and illustrations add to the ease of developing concepts of machines. (Easy)

What Is a Machine? by B. John Syrocki, Benefic Press, 1960. Explains the fundamental simple machines, with narrative and many pictures. Includes a chapter on big machines made up of two or more simple machines. Explains the relation of force to the work of machines. (Easy)

What Is Energy? by Daniel Q. Posin, Benefic Press, 1962. Provides an overview of the subject. Includes these topics: Energy from the Sun; Atomic and Nuclear Sources of Energy; How Heat, Light, Sound, Electrical, and Magnetic Energy Create Force; and Future Sources of Energy. Contains many pictures and diagrams. (Average)

**The Wonderful World of Mathematics* by Lancelot Hogben, Garden City Books, Doubleday, 1955. Interrelates the historical development of science and mathematics. Describes the gradual interchange of knowledge among widely differing civilizations. Starts with consideration of the beginning, about 25000 B.C., to the industrial world today. Selected sections and topics will be enjoyed by average readers. (Advanced)

► INTRODUCING THE UNIT

What kinds of machines have you used today? After a few have been listed, ask if any pupils have machines that are part of themselves? A show of skepticism, at least on the part of some pupils, may be expected. Suggest they try to pick up a book without using their thumb or open a window without bending their elbow. As soon as there is some agreement to the idea that a simple machine helps us do something with less effort, turn to the opening of the unit (text pages 152-53), read the text, and then find answers to the questions in it by examining the illustration.

How do machines really work? Do some work better than others?

(Text pages 154-60)

SUBCONCEPT

Machines may multiply force, increase speed, or change direction.

Section 1: MULTIPLYING THE FORCE OF YOUR MUSCLES

Pupils examine the three types of simple machines and discover some of the relationships between the effort used to move an object and the distance it is moved. Machines reduce effort by multiplying force, but do not give us something for nothing.

Introducing the Concept

How *strong* are you? Does this mean how much you can push or pull, lift or carry, how fast or far you can run or walk, or some other idea? Are you strong enough to lift a piano (or another familiar large and heavy object)?

Can you design a way you might be able to move a piano or a heavy crate into a truck? Several strong men could lift it, but you can't have any help; you have to do it yourself. Let us make believe that this chalkbox (or pile of books) is the back of a truck. Can you make, with this length of wood (a yardstick or orange crate slat), a model of a machine that you could use? If you were in a wheelchair, could you invent a way to go up some steps? Encourage pupils to consider, as they read and investigate, these questions:

What is a simple machine? What do simple machines do? How many machines can you think of?

Developing the Concept

An investigation into an inclined plane. After the pupils have read the three introductory paragraphs on page 154, ask if, to reach the floor above, they would rather shinny up a rope, climb a ladder, go up stairs, or walk up a ramp. Which is easiest; that is, which seems to take the least effort? Do you think there is any relationship between the apparent effort and the distance covered? Let us find out. Groups of pupils may work together on the investigation on text page 155. Since investigations into machines require some mathematical computations, pupils should be instructed to keep careful records of all measurements and calculations. A tabular form for recording results may be devised, and modified as the work proceeds. Pupils may need to practice giving a slow steady pull on the spring scales in order to attain accurate readings.

Come back to the questions with which you started this activity. When you climb stairs or shinny up a rope, what weight must you move? (Your own.) How much effort will you need to shinny up a rope? (Amount equal to weight.) To climb stairs? (Maybe equal to half one's weight, depending on steepness of the stairs.) How would you build stairs for invalids or elderly people? (More sloping.) In how many ways do people use inclined planes? With a few ideas as starters (subway ramp, escalator, playground slide, house roof, etc.), pupils will think of many other examples. What relation is there between effort and distance in all these examples where they are used as machines?

An investigation into the lever. A group of students may perform this investigation while another group designs an investigation of its own into the pulley, as suggested below. What kind of machine would you use to pry a heavy stone out of the ground? Encourage development of a model, as for the inclined plane above, using the same equipment. Where would you apply the effort? What change could you make to multiply the effort? (Move the fulcrum closer to the stone.) Verification of the pupils' hypotheses should result from the investigation on text page 157.

An investigation into the pulley. What does a fixed pulley do? Are there any in the classroom? Would you rather pull up a window shade from the bottom, or pull it down from the top with a pulley system? Is one way easier than the other? Does one way take more effort? Set up an investi-

Equipment and Machines

... box or pile of books
... length of wood or a yardstick

The effort needed to raise a weight a given distance decreases as the length of an inclined plane is increased.

Processes emphasized

Investigation (with design of an experiment)
Mathematical computation
Measurement (observation)
Library research
Recording
Invention
Hypothesizing
Theorizing
Predicting
Analysis of data

Equipment and Materials

See text page 155; also the Teacher's Manual for Classroom Laboratory 6.

The effort needed to raise a weight with a lever depends on the relative distances of the load and the effort from the fulcrum.

Equipment and Materials

See text page 157; also the Teacher's Manual for Classroom Laboratory 6.

A fixed pulley changes the direction of a force; it does not multiply the force.

Equipment and Materials

- ... fixed support with pulley
- ... cord and weight
- ... spring balance

One use of the wheel and axle is to increase speed.

gation to verify or disprove the pupils' hypotheses. All the equipment needed is a fixed support to which a pulley can be attached and move freely, a length of cord, a weight, and a spring balance. What does a fixed pulley do? (Changes direction of the force—no multiplication of effort.)

Investigating the wheel and axle. The textbook describes one way of investigating what a wheel and axle does. An interested group of pupils may design their own investigation and report to the class.

Concluding the lesson. Several types of simple machines have been investigated. The textbook (page 159) summarizes concepts that the pupils will have discovered and should have verified. How have engineers used these concepts to invent many kinds of machines combining these few simple ones? A chalkboard list may be developed. It probably will include many compound machines, but return to these later in the unit. Give pupils credit for recognizing simple machines used in combination with others. What three benefits do machines give us in doing work? Pupils may correctly indicate a further advantage in the release of time for scientific investigation and technological inventions.

Extending the Concept

The machines we use. Compile a list of the machines you use in one day. Did you use some to multiply effort? Some to gain speed? Some to change direction? Develop a report on your investigation. Perhaps you can find out how recently some of the machines were invented.

A report. Ramps have been found in the ruins of ancient temples of Babylon. Great slabs of rock were lifted great heights to build the pyramids of Egypt. Interested pupils may read to investigate the kinds of machines Babylonians, Egyptians, Mayans (in Central America), and other ancient peoples used in building their cities.

Reviewing the Concept

Before You Go On. A. 1. a 2. c 3. b

Using What You Know. 1. Wheel and axle and possibly a pulley on the window shades; pulley on the venetian blinds and possibly a wheel and axle to change the tilt of the slats. 2. An inclined plane.

Section 2: THE LEVERS YOU USE

By investigation, pupils discover that the location of the fulcrum in relation to load and effort affects the amount by which a machine multiplies force. They learn the different ways in which levers can be applied to move objects. They discover that the fulcrum may be located in three positions in relation to the load and effort.

(Text page 160)

(Text pages 161–65)

SUBCONCEPT

A lever is a simple machine that concentrates the effort force and the load, each at one point; a lever usually multiplies force.

Introducing the Concept

Suspend a yardstick so that it hangs freely and is balanced around its midpoint. How can we show that this acts like a lever? What does the point of support resemble? (Fulcrum.) Let us hang a weight (say 50 grams) 8 inches from the fulcrum. Where will you have to apply just enough effort to balance the weight? How can we test our hypotheses? (Use a spring scale.) As volunteers test (one should lightly support the weighted end until the spring scale is attached and can be held), they will, of course, find that the spring scale will register 50 grams at 8 inches from the fulcrum on the side opposite the weight when the spring is *pulled down* at the point—and nowhere else. Where can we apply a force so that *less* force is needed to balance the 50-gram weight? (Nearer the end of the yardstick.) If you wish to suggest that there is another kind of lever, you may ask where else a force might be applied so that there will be a balance of forces. Volunteers who propose a hypothesis should be asked to test it. (The spring scale *pulled up* exactly at the point the load is attached.) What do we notice about the location of the effort force? (It seems to be concentrated at one point.)

Before the pupils begin the investigation on text page 162, you may wish to make a preliminary exploration of these questions and encourage hypotheses:

How can we apply effort to multiply force by using a lever? How will changing the location of the fulcrum or the point at which effort is applied change the amount of the effort?

Developing the Concept

Investigating the location of the fulcrum. As the pupils investigate different locations, it is well to insist on tabulating exact measurements. With some classes, you may be satisfied with an answer to the questions “more” or “less,” but with many you will wish to investigate “how much more” or “how much less.” Only mathematical computation can give a good answer; hence, exact measuring is essential. The measurements to record at this point should be (if a yardstick is used) *location of fulcrum (F)*, *weight of load (L)*, *distance between load and fulcrum (LD)*, *distance between fulcrum and effort (ED)*, and *amount of effort applied (E)*.

After several sets of data have been obtained, encourage inspection of relationships. You may wish to place on the board the equation $L \times LD = E \times ED$, and develop the relationship that as ED becomes greater, LD becomes less. For example, if L is 50 grams and LD is 3 inches, ED at 6 inches will require 25 grams of effort. Can the pupils see that the relationship between L and E is 2, and the relationship between ED and LD is also 2? The lever with the fulcrum located in this position multiplies the effort by 2. This figure is the *mechanical advantage* of this lever setup, if you wish to introduce the term.

Examining levers. Either have on hand for examination samples of levers or encourage pupils to bring them in. For example, claw hammer,

Processes emphasized

Investigation (with design of experiment)
Measurement (observation)
Analysis of data
Mathematical computation
Library research
Invention
Hypothesizing
Theorizing
Prediction

Equipment and Materials

... yardstick
... support
... string
... weights
... spring scale

Moving the fulcrum in relation to load and effort increases or decreases the effort that must be applied to lift a load.

Equipment and Materials

See text page 162; also the Teacher's Manual for Classroom Laboratory 6.

The longer the effort arm, the more a force is multiplied.

A block-and-tackle pulley system multiplies the force by the number of ropes that support the load.

Pupils test their understanding of pulleys by considering several situations in which they may be used.

Investigating the block and tackle. Similar results should be obtained as in the investigations described above. With three pulleys in a block-and-tackle system, one third the effort is needed; the load will rise one third the distance with the same amount of rope, or the same distance with three times the length of rope.

Problems with pulleys. After pupils have finished reading their text and have considered the problem at the end of the section, test comprehension by problems similar to the following:

1. Suppose an automobile engine needs to be removed from the car frame in order to repair it. The engine weighs 600 pounds. What arrangement will be needed to raise it with only 100 pounds of effort? (A block-and tackle with 3 pulleys in each block.) Can you diagram the arrangement? (There should be 6 ropes plus the one that changes direction of the effort.) How many feet of rope will be pulled through the system to raise it 5 feet? (30 feet.)
2. How would you hang a mirror so that it could be raised for tall persons and lowered for short persons?
3. What kind of pulley arrangement could you set up to tighten a wire stretched across the room, as for a time line? Assume that the effort to tighten the wire is one fourth the tension on the wire in pounds.

Extending the Concept

Pulleys reduce friction. Using a spring scale, a length of cord, and a weight, measure the effort needed to raise a weight when a rounded surface, such as a chair back, is used instead of the fixed pulley. Compare with the measurement using a pulley and the same weight. In pioneer days, when a wagon train had to cross a river with steep banks, ropes were tied to the wagons and then snubbed around trees and the length gradually let out as the wagons were eased down the trail. Usually, we want to reduce friction rather than make use of it in a rope system. Why is a pulley useful? It reduces friction, and friction can be reduced still more by greasing the axle around which it turns.

Multiplying force without pulleys. Select two strong boys each to hold a broomstick. Fasten one end of a length of rope to one broomstick. As the boys stand two feet apart, pass the rope back and forth around the broomsticks six or eight times. Do you think the smallest girl in the class can pull the broomsticks together? Arrange a demonstration if possible.

A pulley display. Where are there pulleys at work? Flagpoles, venetian blinds, ski tows, building cranes, etc. Pictures from magazines and newspapers are a ready source of display material. Working models from toy sets can also provide other examples. To each should be attached a description showing how it reduces the force needed to do a given task.

The metric system. Interested pupils may be encouraged to consult library references and develop a conversion table from English to metric system, or from one unit to another in the metric system. Upon what system in mathematics is it based? (Decimal.)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. a

On Your Own. The distance will equal the number of strings times the distance the load is lifted. For example, $4 \text{ strings} \times 1 \text{ foot} = 4 \text{ feet}$.

Section 4: OTHER MACHINES YOU USE

The pupils examine their experiences to see that the great variety of machines are really combinations of simple machines. Most of them change the direction of a force, multiply a force, or increase speed.

Introducing the Concept

If there is a school shop, arrange to borrow various common tools—a chisel, a wedge, a screwdriver, various kinds of screws, nuts and bolts, a few nails, a hand drill (if possible), wrenches, and some pieces of wood $\frac{1}{2}$ to 1 inch thick. Or arrange with the school custodian for a loan of similar tools for a class period, or the day. Ask the pupils to state—or guess—what the tools are used for. What kinds of machines do they represent? Are any of the tools combinations of several different machines? A central question to this section is:

Can machines be combined to multiply force or gain speed?

Developing the Concept

Uses of screws. After pupils have read the introductory paragraphs and examined the illustrations, proceed to the investigation on text page 173. The pupils may need help in winding the paper; they should start with the 6-inch side against the pencil and wind so that the 12-inch side rests against the top of the pencil. There will be about 10 “threads” for the average pencil. Examine several types of screws and compare the number of threads in 1 inch. There may be 12 or more, perhaps six to ten times as many in proportion to the model. In the work on the inclined plane in Section 1, what did we find out about the relations of the slope to the force needed to pull an object up it? (The longer the slope the less the force.) Compare with the model screw and the sample screws. What resistance must a screw overcome? (Friction—actually the cohesion of the molecules in the substance into which it is driven.) Why is it easier to pry two boards apart when they are fastened with a nail rather than a screw? The inclined plane on the screw has greater force acting against the force of the pry (lever).

The movable inclined plane. The screw was a kind of moving inclined plane. If we put two inclined planes back to back, what kind of machine do we have? (A wedge.) What does it do? (It, too, overcomes friction—or molecular cohesion.) On the basis of what you know about the effect

(Text page 171)

(Text pages 172–79)

SUBCONCEPT

Most machines are modifications or combinations of a few simple machines.

Processes emphasized

Invention (model-making)
Analysis of observations
Mathematical computation
Hypothesizing
Theorizing
Prediction
Investigation (study of machines in the environment)

Equipment and Materials

... various tools, as suggested

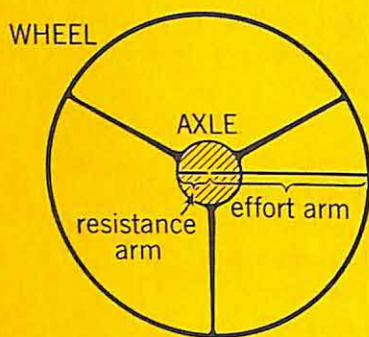
A screw is a winding inclined plane.

Equipment and Materials

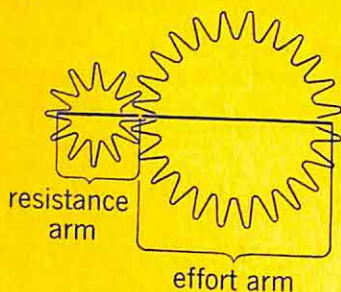
See text page 173; also the Teacher's Manual for *Classroom Laboratory 6*.

Wedges are movable inclined planes for overcoming great resistances.

A wheel and axle multiplies force when it is applied to the wheel, and increases speed when it is applied to the axle.



Gears multiply force or increase speed as the wheel and axle does, and change the direction of the force.



Compound machines multiply the forces of the simple machines of which they consist.

of the slant of an inclined plane, would you use a thin wedge or a thick wedge to try to split a hardwood log? (The thin wedge; the less the slope, the less the force needed.) What are some movable inclined planes you use? Pupils expand on the examples given in their text. A nail and a needle are actually wedges that have been rotated to form a point.

A spinning lever. If possible, take off a doorknob, as suggested on text page 175, by removing the small screw on the shaft and slipping off the knob. Try to open the door by turning the axle with the fingers. Most axles have a hole through them into which the set screw fits. Insert a long nail and try to turn the axle. What does the long nail resemble? (A lever.) Place on the board the diagram at the side. Which distance represents the effort arm? Which the distance arm? What is the relationship, the mechanical advantage, if the wheel radius is 2 inches and the axle radius is $\frac{1}{4}$ inch? (8.) When the effort moves through a whole circle, a wheel is described; so we can call the wheel and axle a spinning lever if we wish.

Suppose you have a bar-type lever with the load 12 inches from the fulcrum and you press down 3 inches from the fulcrum at the opposite side. It takes more effort force, but how far does the load travel if the effort travels 1 inch? (4 inches.) If you turn the axle through a full circle, how much farther will the edge of the wheel travel if the radius of the axle is 2 feet and the wheel is 6 feet? (Three times as far.) This means that the big wheel goes three times as far in the same time as the little axle; hence an increase in speed. (Incidentally, an increase in speed gives a fractional mechanical advantage of $\frac{1}{3}$, if you feel the class is ready for this refinement of concept.)

Uses of gears. A similar analogy to the lever may be developed with gears by using the diagram at the side. Most gears connect the effort arm and the resistance arm by means of teeth. In the bicycle, however, a chain synchronizes the turning of the wheels and transmits the effort from the sprocket wheel to the traveling wheel, *without change of direction of the force*. All meshed gears change direction. Up-end a bicycle and count the teeth on each wheel. If the larger wheel has 50 teeth and the smaller has 10 teeth, how many times should the rear wheel turn for every complete turn of the pedals? Verify by sticking a piece of adhesive tape to a spot on the tire and counting the number of turns it takes for one turn of the sprocket. The mechanical advantage of gears is usually figured by the ratio of the number of teeth. Gears, like wheels and axles, may multiply force or increase speed.

Machines in combination. Throughout this section, you have been combining machines and using compound machines. In what two ways do you use a screwdriver in opening a paint can? (As a wedge to get under the lid and as a lever to pry it off.) What type of machine is a wrench? When you tighten a screw, how do you use a screwdriver? (As a wheel and axle.) Can you drive a nail without using another kind of machine? (No. Two levers—in the arm and in the hammer.) What is the advantage

of combining machines in this way? (The force of one machine increases the force of the other; that is, the mechanical advantage of one *multiplies* the mechanical advantage of the other.)

Your textbook mentions a number of compound machines. What machines are there in a meat grinder? (Wheel and axle turning an inclined plane.) What machines are there in the egg beater? (Wheel and axle turning a small gear connected to other gears that change direction of the force.) Do these machines increase force or increase speed? (Force.) If you borrowed a hand drill, you may wish to show how it works. A wheel and axle turns gears. What do the gears turn? (An inclined plane.) The bit, when turned in a piece of wood, shows that the wood has "climbed" the inclined plane. The pupils may cite other examples.

Extending the Concept

Compound machine display. The science display table or the bulletin board can be enlarged by adding toy models or photographs of hardware tools showing a compounding of machines. Descriptions of what these combinations do should be attached to all models displayed. See Chapter 25 of *The Sourcebook for Elementary Science* for suggestions.

Arranging a visit from a repairman. A committee of pupils may select a local repairman and invite him to talk to the class on the use of tools. They should brief him on questions they would like him to discuss. Among them might be: What is the right way to use a screwdriver? A chisel? When and how should you use screw clamps, wrenches, and other tools with devices having threaded surfaces? Why are there so many kinds of screws? What kinds of drills are there and when and where are they used? How are pipes kept from leaking? What kinds of tools are used to get at out-of-the-way places? The class should add others.

(Text pages 178-79)

Reviewing the Concept

Before You Go On. A. 1. a, b 2. b 3. b 4. a, b

Using What You Know. 1. b; The slope of the winding inclined plane around the screw offers more resistance than the smooth nail. 2. b, d, e, f

(Text pages 180-83)

Section 5: A RESISTING FORCE

The pupils investigate ways in which friction causes an increase in the effort force needed to move objects over a distance in the same amount of time. They discover that most machines are designed to reduce friction, but that some machines make use of friction.

SUBCONCEPT

Friction increases effort that must be applied, and decreases speed (distance).

Introducing the Concept

NOTE. In the first four sections of this unit, the pupils have been investigating the ways in which a machine multiplies the force used to move a load, changes the direction in which the force operates, or applies a force

Processes emphasized

Observation

Investigation (with design of experiment)

Analysis of data

Invention

Computation

Hypothesizing

Theorizing

Prediction

Library research

to gain speed (or more distance, in the same amount of time for the force applied). Each force thus far studied has been concerned with application of the effort force. In this section, the pupils consider the resistance (load) as a force that slows down the forward motion of objects. Is friction ever useful? Or should we try to develop a machine that would never stop (perpetual motion)?

We live in a world of motion. You may wish to start discussion by asking if there are times when we wish to keep things from moving or bring them to a stop? What are some of these things? (Automobiles, sleds, etc.) What force is used? (Friction.) Have we met this force in any of the machines we have studied? (Yes; in all of them.)

Let us look at friction. Place objects at the top of a smooth metal tray—marbles, round pencils, hexagonal pencils, blocks of wood of several sizes, flat plastic objects such as combs, glass objects such as square-sided medicine vials, and metal objects such as spoons or knives. Tilt the tray slowly. Record the sequence in which the objects start to slide. Why didn't they all start to slide at one time? Pupils hypothesize. These questions can be investigated:

When two surfaces are in contact, what effect does the amount of surface in contact with another surface have on the motion of an object? Does the kind of surface have any effect? Does the weight of the object have any effect?

Developing the Concept

Investigating the force of friction. The first two paragraphs of the text lay the groundwork for the investigation. Actually, the pressure exerted by the skates against the ice melts some of the ice, and the skater glides over a film of water. How does sand or dust that has blown over a frozen pond make skating difficult? A number of conditions are suggested in the investigation on text page 181. You may wish to divide the class into several groups, each to investigate a different condition. The first part of the investigation deals with sliding friction (two surfaces in contact), and the second part with rolling friction (a point on a round surface in contact with a flat surface). Increasing the weight increases the pressure of one surface on another, thus making the contact between surfaces closer. Thus, gravity (weight is a measure of gravitational pull) increases the amount of friction. Friction, therefore, is a force acting in one direction. And effort is a force acting in the direction of the pull or push given an object. One force must overcome the other for motion to take place.

After the results of the investigation have been recorded, inquire: How can the resisting force of friction be reduced on a flat surface? (Smoothing, lubricants.) How can it be increased? (Roughening the surface.) If a door opens with difficulty, perhaps with a squeak, what force is at work? (Friction.) How would you correct it? (Oil.) Oil or grease fills in the rough spaces in a surface, providing a smooth film on which the sliding surfaces move. The molecules in the more or less liquid oil are freer to move. How

Friction is a force that resists motion.

Equipment and Materials

See text page 181; also the Teacher's Manual for *Classroom Laboratory 6*.

does using wax or soap make it easier to open windows or drawers that tend to stick?

Investigating surfaces. Encourage close observation of different surfaces with a magnifying lens—table tops, blotters, rubber matting, etc., as well as aluminum foil, wax paper, etc. What surfaces will offer the greatest resistance to a force applied to put an object on them in motion? Or blindfold yourself and have a friend place different kinds of surfaces in front of you. Feel them with the fingertips and indicate which surfaces will offer the most friction. Verify by the techniques in the investigation on page 181.

Rolling friction. In addition to using the juice can as suggested in the investigation, use a baby food or mayonnaise jar. Mark the line where it is in contact with a surface. As you roll the jar, what happens to this contact line? (It moves off the surface and is replaced by another line.) Compare with a wheel. What happens if the surface becomes smooth, as an icy road may in winter? (The wheel skids.) How can we prevent skidding? Pupils may wish to examine tire treads to see how they “grip” a surface, or investigate why sand is spread on highways. Highway departments also often spread chemical substances to melt the ice. Why? (The roadway beneath has a rough surface.)

Using the force of friction. Is friction ever useful? Recall from Section 4 that friction against the winding, inclined plane of a screw binds objects together. What force do you make work for you when you brake a bicycle? Different kinds of bottles and other containers use friction caps. You may tighten a screw cap on a jar and let pupils try to remove it, noting how much force they must use to overcome the friction. Other forms of useful friction may be cited. Incidentally, the wheels of a railroad train are made of cast iron while the rails are made of steel. The cast iron provides enough friction at the point of contact to give the locomotive traction.

Extending the Concept

Friction and the inclined plane. How could you reduce the force of friction on an inclined plane so that you could drag a heavy crate up it with less effort? Using the equipment suggested in the investigation, devise an investigation to measure the difference in effort with different surfaces. How would rollers (dowel pins or round pencils) affect the effort needed?

Is energy lost in overcoming friction? Rub your hands together rapidly and notice the friction. What else is felt? (Heat.) Now drive a nail into a block of wood and pull it out with a claw hammer. Feel the nail. Investigate what happens to engine parts and electric motors when they are not oiled. (The energy that provides the force to move the parts is converted to heat, the effect of which is damaging to the machines.)

Making a ball-bearing model. Set a bucket of sand on some marbles and rotate the bucket. The marbles reduce the friction. Collect jar lids of three sizes so that one will nest in the other. Place the smallest lid inside

The amount of friction depends upon the kinds of surfaces that are in contact.

The less two surfaces are in contact, the less the friction between them.

Friction is sometimes useful.

Equipment and Materials

... bucket
... sand
... marbles
... 3 sizes of jar lids

(Text pages 182–83)

(Text pages 183–88)

SUBCONCEPT

Work is done only when an object is moved through a distance.

Processes emphasized

Inference
Hypothesizing
Theorizing
Concept formation
Testing
Investigation

A simple machine multiplies effort but does not increase work.

Equipment and Materials

See text page 185; also the Teacher's Manual for *Classroom Laboratory 6*.

The pupils infer relationships and develop an equation for work.

the middle-sized lid with a ring of marbles in the space between. The largest lid should rest on the marbles and clear of the table. Place a weight on the jar lid and spin. The pupils, using this as a model, may surround it on the science display table with examples or illustrations of machines using ball bearings—roller skates, as one example.

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. a

Using What You Know. Use the small logs as rollers.

Section 6: IS MORE WORK DONE?

The pupils review some of the simple machines they have studied and discover that the amount of work done, in the scientific sense, is a relationship between the force needed to move an object and the distance through which it moves.

Introducing the Concept

Do any of the machines we have studied help us do more work? Do you do less work, for example, in using an inclined plane to move a piano into the back of a truck than if three persons helped you lift it straight up? Would you do less work by using a pulley system or would some other machine be better? Are you doing work if you can't move a car no matter how hard you push it? Allow for discussion and formulation of hypotheses. What work were you trying to do? Did you really do any more work with the machine?

What is work?

Developing the Concept

The work of a simple machine. After the pupils have read through "A New Concept of Work" call for any revision they may wish to make of their hypotheses. It may be useful to narrow the question by introducing the modifying adjective *useful*—since pupils have found that in some of their investigations friction makes a difference in the effort needed. Have the pupils proceed to plan and perform the investigation on text page 185. The roller skate reduces the frictional factor to a relatively negligible quantity. It is desirable that as many small groups as possible work through the investigation, so that pooling of results can be used to fix the concept.

Work equals force times distance. How does work done in both parts of the investigation compare? (It is the same.) How does the effort measurement change, using the inclined plane? (It becomes less.) How does the distance measurement through which the skate is moved change? (It is longer.) Can we set up an equation to describe this relationship? Once

an approximation has been voiced, place the equation $W = F \times D$ on the chalkboard. What are $F \times D$ when the skate is lifted? When it is pulled up the plane? The work done is seen to be approximately the same in both instances; although it will be seen that friction has an effect. What has happened to F (effort) in the second instance? You may wish to introduce the unit of work which is measured by combining units of distance and units of weight, as **foot-pounds, inch-ounces**. How much work could you do if the effort is doubled? (Twice the amount.) Can you now see how the machine multiplies effort? It makes work *easier*, but you don't do more work unless you change the effort you put in.

Investigating the pulley system. Pupils may be encouraged to set up various pulley systems and use various weights as described on text page 187, if class time permits additional investigations. They will again discover that $W = F \times D$.

Extending the Concept

Investigating work and the lever. How does a lever illustrate the concept of work? Let the pupils design an investigation to find out. For example, place the fulcrum so that the effort arm is four times as long as the resistance arm. The work done is, of course, the weight of the load times the height it is lifted, and equals the amount of effort times the distance through which the effort moves. How does the effort vary with the distance from the fulcrum at which it is applied? How does the distance the effort moves vary? How does the placement of the fulcrum affect the work done? Does the load times the height it is moved always equal the effort force times the distance it moves?

Investigating the effect of friction. In Section 5, pupils investigated the effect of the types of surfaces on the effort needed to move an object. If surfaces are rough, as on an inclined plane, is more work done to raise an object 1 foot than if friction is reduced? The investigation on page 185 may be set up in the same way, substituting a block for the roller skate. How do you explain the difference in the measurement of the effort force? Perhaps the force needed is $2\frac{1}{2}$ pounds. A half pound of effort must have been used to overcome friction. The *actual* work done seems to be more than the work we set out to do. With every machine, the work put in is always a little more than the work got out. Engineers must take friction into account in order to know how much additional effort needs to be supplied in order to design machines that will do a given job. Sometimes we want friction to work for us. A small force applied to the brakes on a car increases the friction. Soon the force of friction stops the forward motion. Friction reduces speed and decreases distance.

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. a 4. a

Using What You Know. The correct answer is b.

Pupils verify the concept by investigating a different machine.

(Text pages 187-88)

(Text pages 189-91)

CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

UNIT CONCEPT

The amount of energy gotten out of a machine does not exceed the energy put into it.

Where does the force to do work come from?

How do tools multiply force?

What does work output mean?

How do you measure work input?

Does work input always equal work output?

On Your Own. Archimedes could have used a wheel and axle with a movable pulley or a block and tackle, for example. The effort must move 100 feet.

Section 7: THE MAIN CONCEPT: ENERGY, MACHINES, AND WORK

The pupils relate the concept of work to the larger concept of energy and its transformations. They see that the energy that furnished the effort force to move machines is transformed into work and another form of energy. Work input is equal to work output. Energy is neither lost nor gained.

CONCEPT SUMMARY

When you push down on one end of a lever to raise a load, pull on a rope in a pulley system, or turn the wheel of a wheel and axle, where does the force come from? Of course it is supplied by the energy in your body. Where did you get your energy? Pupils review their earlier understandings of sources of energy, and trace their own energy through the food they eat, to the green plant, and eventually to the sun. To what kinds of energy is the sun's energy changed in this sequence? From radiant energy to stored chemical energy to mechanical energy, when a force is applied to move an object. At this time, pupils may be encouraged to read the section and hypothesize whether energy is used up when work is done.

How would you like to build a highway with garden tools? At one time men did just that. They moved dirt with a shovel instead of a bulldozer. Tools are an invention that extends man's hands and arms. These questions may be explored and resolved: How is a hammer an extension of the lever in a man's arm? Or a nutcracker an extension of the levers in his fingers? Or a wheel an extension of the ball-and-socket joint in his shoulder and the lever in his arm? Can you see how tools (simple machines) multiply the force that the energy in food provides the simple machines that are part of man's body?

When you have a piece of work to do, how do you measure the amount? (Multiply the distance by the weight of the load you want to move.) Pupils cite examples from their investigations to support their answer.

When you use a machine, how do you measure the amount of work you really have to do? (Measure the effort force and multiply it by the distance the effort force travels.)

Let us assume some figures for the work input and work output of a machine. In pulling a block up an inclined plane, the length of the plane times the weight of the load (work input) equals $2\frac{1}{2}$ foot-pounds. Lifting the same load the same vertical distance (work output) is 2 foot-pounds. It would seem that some of the energy put into the machine has been lost. But has it? What has happened to that extra half foot-pound? Review with the pupils that as surfaces rub against one another, heat is

generated, and that heat is a form of energy. As the pupils will discover in Unit Five, heat energy can also provide a force to do work. Some of the energy put into the machine is got out as heat energy—a kind we don't want with simple machines.

Ask what Archimedes meant when he said, "Give me a place to stand and I will move the earth." How could this statement be applied to the lever? (A long enough effort arm would multiply force enough to move a large mass.) How does what you have learned suggest ways to select the right tools for a job? For example, would you use a small-handled or a large-handled screwdriver to turn a large screw? Would you choose a small wrench or a large one to join two threaded pieces of pipe together? Why should a bicycle be oiled regularly? Encourage pupils to suggest inventions that would multiply force or reduce resistance.

How can the concepts of machines help you in using tools?

(Text pages 190–93)

FIXING THE MAIN CONCEPTS

Testing Yourself. 1. b 2. a 3. a 4. a and b are true, but c is false; a machine does not produce energy, but merely transmits it. 5. Pupils' answers; check with the glossary on text page 422.

Quick Test. 1. (Left) wheel and axle, inclined plane, wedge; (right) screw, pulley, lever. 2. a. Wheel and axle, circular wedge, gears. b. Two levers with wedges as the cutting edges. c. Wheel and axle, inclined plane (or screw). d. Lever, (pointed) wedges. 3. Pupils' answers; they should cite machines, such as a lawnmower or motorboat, in which there may be more than one of each simple machine. If they recognize a wheel and axle as a spinning lever, a meat grinder or pencil sharpener is a good illustration.



UNIT FOUR

MACHINES IN ACTION

Look at the picture. It is a scene of a favorite sport of many people all over the world. Study the picture carefully and then see if you can answer this question: Would you say that work is being done? A scientist would, but he has a special reason for describing the action as work. Do you know the reason? How many things can you identify as machines? When you have finished studying this unit, look back to this introduction and once again list all the machines that you find in the picture. You may be surprised.

Machines are a part of our daily life. Today, we could not get along without them; but in the beginning, they all started as extensions of the human body—to assist in the action of the muscles in your arms and legs. For example:

Suppose you tried to lift your father with one hand. Could you do it? Perhaps you are not strong enough, but the picture on top of the next page shows how you might do it by using a machine to multiply the force of your muscles.

From the Stone Age cave dweller's first attempts to make tools to man's fantastic success in the technology of today, man has applied his mind to invention. This unit explains how man uses his brain and hands, his imagination and skill, to change his environment and let machines do his work.



MULTIPLYING A FORCE

1. Multiplying the Force of Your Muscles

Andrew had hurt his leg and had to use a wheelchair to move about. The door to his home, however, was two steps up from the sidewalk. Andrew's muscles could not supply enough force to lift him and the wheelchair up the steps together; so how could Andrew get up the steps in his wheelchair?

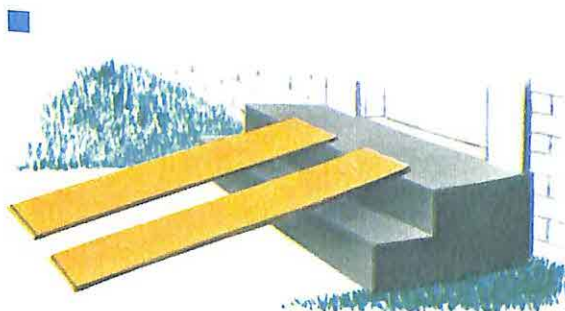
Andrew's father laid boards over the steps to make an **inclined plane** (in-klind' plān). ■ Then Andrew could move from the bottom of the first step into the house. Andrew was using a **simple machine**, an inclined plane, to help him get up the steps.

An inclined plane is a simple machine, but what makes an inclined plane a simple machine? The investigation on the opposite page will help make the concept of a simple machine easier to understand.

An Explanation

When you lifted the skate straight up with your hand and arm alone, the entire weight of the skate was recorded by the spring balance. You were using only the force of the muscle in your arm to hold up the skate.

When you rolled the skate up the inclined plane, the plane itself supported part of the weight. The rest of the weight was still supported by your arm. The scale on the spring balance recorded less weight (force), because the inclined plane was helping your arm to support the skate. The inclined plane therefore increased the smaller force you were applying so



AN INVESTIGATION into an Inclined Plane as a Simple Machine

Needed: a roller skate; some books; a spring balance; and a board about 2 feet long

Stack several books to about 1 foot high on a table. Slowly and smoothly, lift the skate with the spring balance from the table to the top of the pile of books. The indicator on the spring balance shows how much **force** is applied to lift the skate. ■

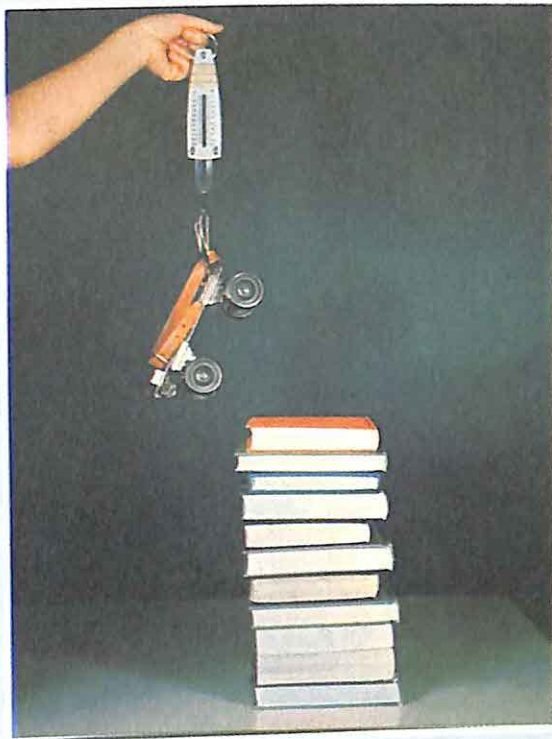
How much force does it take to lift the skate to the top of the books?

Now place the board so that it slopes upward from the top of the table to the top of the pile of books, making an inclined plane, as shown. ● Slowly and smoothly pull the skate with the spring balance up the inclined plane to the top of the pile of books.

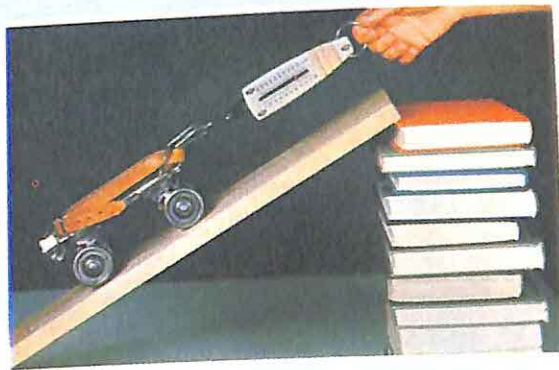
Does it feel as if you are using more force or less force than when you lifted the skate straight up to the top of the books?

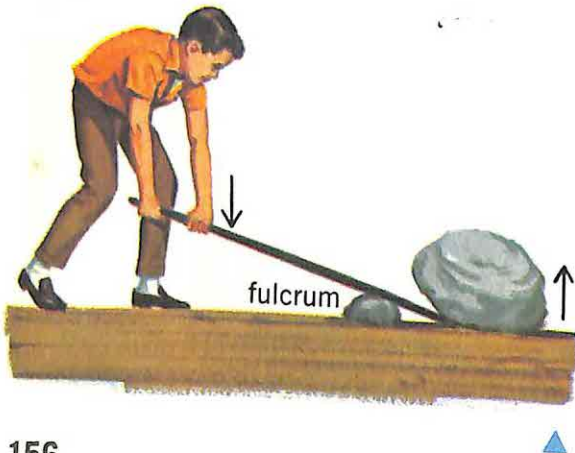
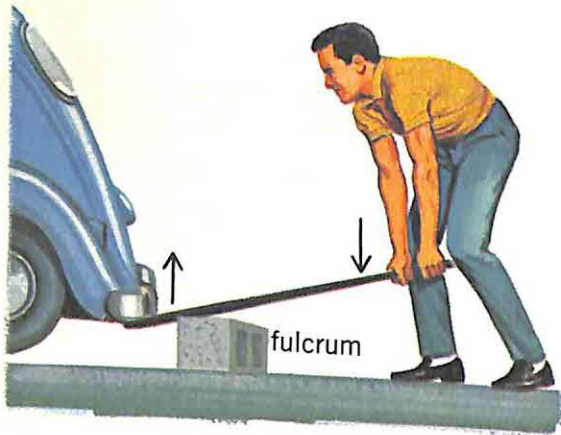
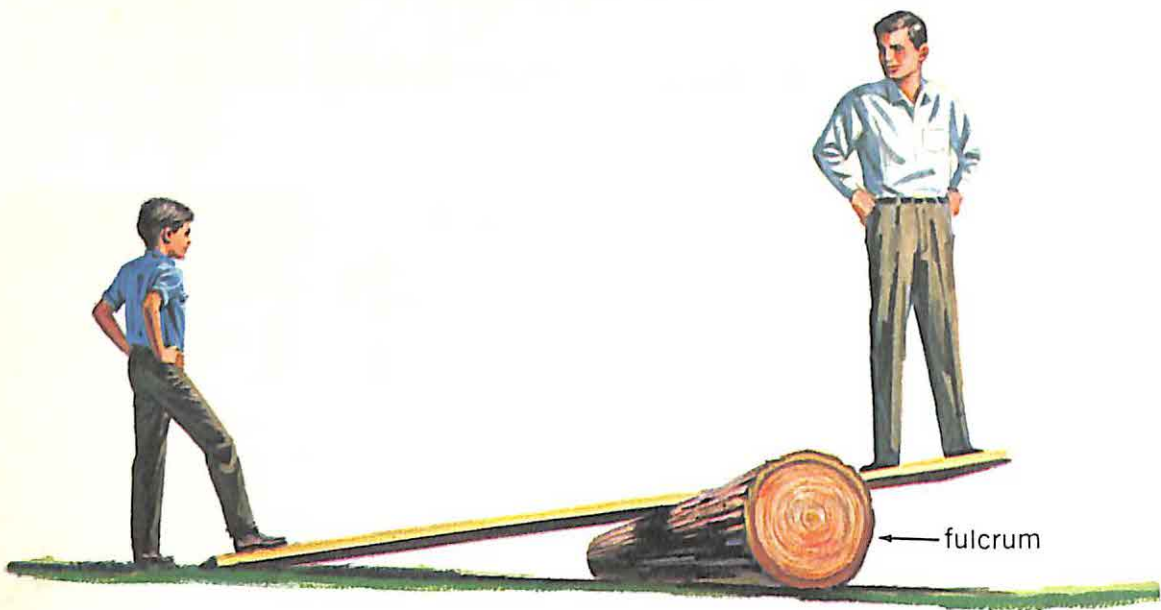
The spring balance again shows how much force is needed to raise the skate to the top of the pile of books.

Now how much force does it take? Repeat the investigation to make sure your results are correct. Does it take more force, the same force, or less force to get the skate to the top of the pile of books, when using the inclined plane? How does this show that the inclined plane is a simple machine?



Additional Investigation: Make the inclined plane steeper by putting more books on the pile. How do you think this will affect the force needed to raise the skate to the top? With the spring balance, measure the force to see if you have predicted correctly.





that you could lift the same weight as before. This is one of the things that simple machines can do; they can *multiply force*.

If you were to lift your father on a jack, the force of your muscles would be *multiplied*. It might take *four* of you to lift a grown man without the help of a simple machine. With a jack, however, one of you can do it alone. There are different kinds of jacks. Each one is made up of simple machines that can multiply force.

You could lift a grown man another way. Look at the picture. ■ The board acts as a simple machine called a **lever** (lev'ər). The log underneath the board is called a **fulcrum** (fōol'krəm). If you push the lever down on one side of the fulcrum, the other side goes up. ● ▲ The fulcrum is the support on which a lever rests and turns. Find out more about a lever as a simple machine by doing the investigation on the opposite page.

AN INVESTIGATION into Another Simple Machine, a Lever

Needed: several books; a 12-inch ruler; the back of a chair; a piece of string; and a spring balance

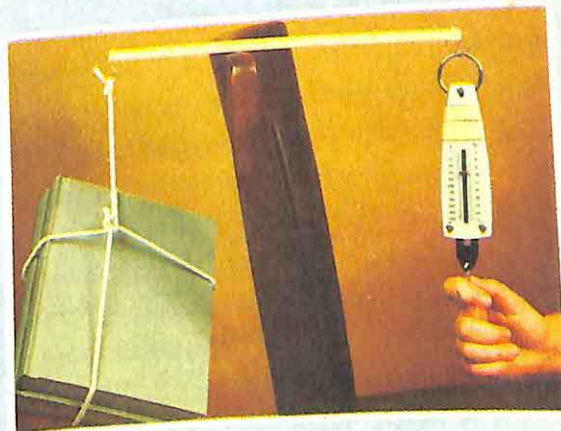
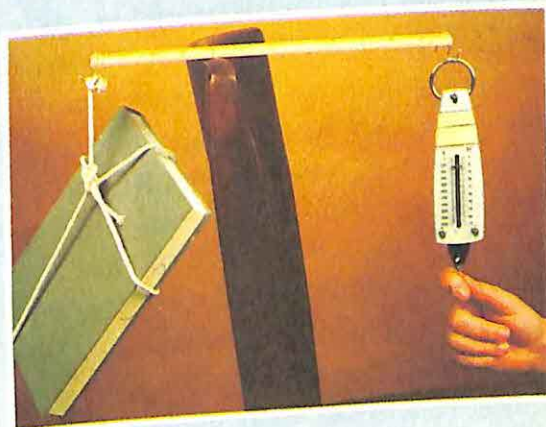
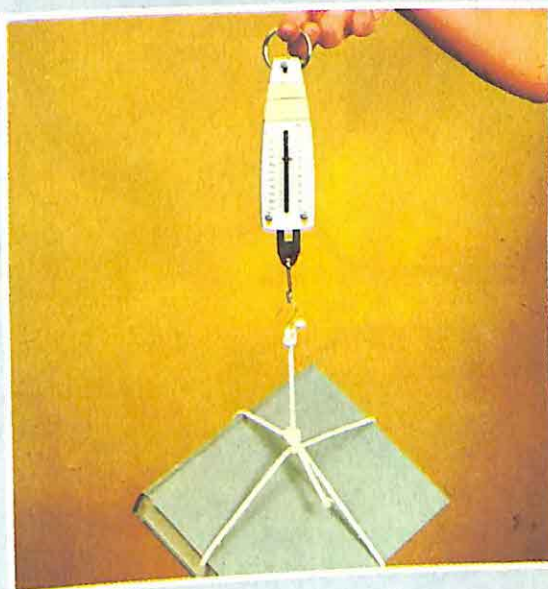
Lift a book using the spring balance, as shown in the picture. ■ How much force must you apply to lift the book?

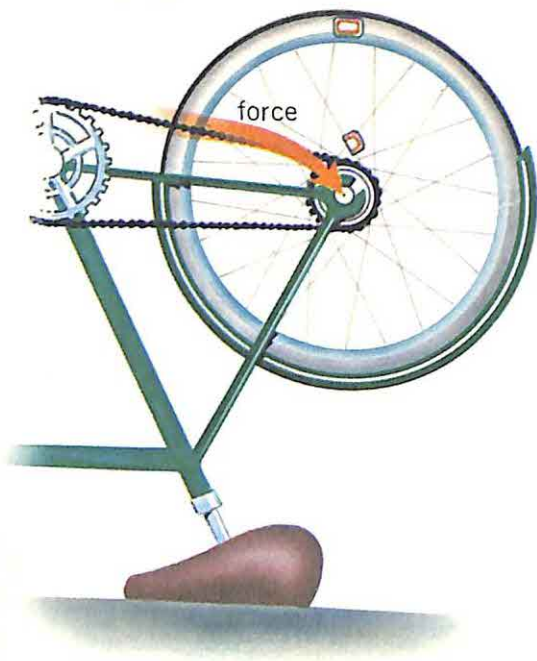
Now use the ruler as a lever with the back of the chair being used as the fulcrum. Fasten the spring balance to the ruler, as shown, and lift the book. ● What does the spring balance read? Are you now applying a smaller force to lift the same book?

Tie another book to the first one, and lift the two books. ▲ Does the lever help you to multiply your force? One person found that the spring balance read about the same when he lifted two books with the lever as when he lifted just one book without the lever. The force of his muscles was doubled because of the action of the lever.

Additional Investigation: Try using the lever to lift several different known weights. For instance, try lifting a weight of 1 pound, 2 pounds, or even 10 pounds. Make a chart and record the amount of force needed to lift each weight. Be sure to keep the fulcrum in the same place.

Before you do the investigation, predict how many times the lever will multiply the force.





The Ways of a Simple Machine

A lever is a simple machine; so is an inclined plane. *Both can increase or multiply force*; but some simple machines can be used for other purposes. Let us study two more simple machines. One of them is the rear wheel of a bicycle or automobile; the other is the pulley used on a flagpole.

Turn a bicycle upside down and examine the rear wheel. ■ It is fastened to a small shaft called an axle. Together they make another type of simple machine called a **wheel and axle**. Turn the pedals slowly, and watch the wheel as it moves. Can you see where the force is being applied to the wheel? Look at the picture. You will see that the force coming from the drive chain is being applied to the axle. Turn the pedals once again. Be sure you know where the force is being applied.

Now place a sticker or a piece of tape on one of the spokes near the axle, and another sticker on the tire at the wheel's outer edge, as shown in the illustration. Turn the wheel again and watch carefully to see which sticker is moving faster, the one nearer the axle or the one on the edge of the wheel. If you are not sure, ask yourself which sticker is moving a greater distance. The sticker on the edge of the wheel moves at a greater speed than the one near the center because it covers more distance in the same amount of time. A simple machine such as the wheel and axle, then, can be used to *multiply speed*.

There is another kind of machine that you have probably seen often, even though you may not have thought of it as a simple machine. Watch a flag being raised. How is it done?

At the top of the flagpole, there is a kind of grooved wheel with a rope around it called a **pulley**. ● The type used on a flagpole is a **fixed pulley**, because it is fastened to the top of the pole. It is not like the wheels of a bicycle, which take you from place to place. Without the help of the pulley and the rope it would be difficult to raise the flag to the top of the pole. It would be necessary for someone to climb the pole each day.

With a pulley, the flag goes up, as the rope is pulled down. The fixed pulley, then, is a simple machine which *changes the direction of a force*.

Look at the picture. The force is in a downward direction while the flag (the load) is going up.

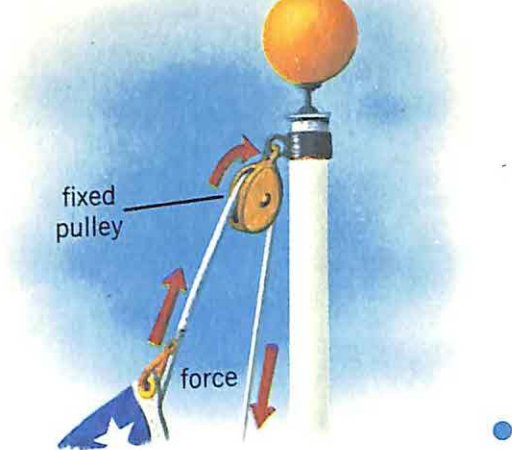
Fixed pulleys are used for many purposes. They are used to hoist a load aboard a large ship, to raise or open the curtain on a stage, and in some schools, to open and close the high windows of the auditorium or gymnasium. Can you think of any other uses for which fixed pulleys may be used about your school or home? Wherever a single fixed pulley is used, the direction of the force is changed by the pulley. Changing direction is another possible use for a simple machine.

Now it would be useful to review what you have learned about the use of simple machines.

Simple machines can increase or multiply a force. You can lift a heavier weight with a smaller force. A lever and an inclined plane are good examples of machines that multiply force. What examples of levers or inclined planes have you used?

Simple machines can increase or multiply speed. Drive wheels on bicycles and automobiles are good examples of machines that multiply speed. In cars, trucks, locomotives, and buses, a force from the engine is applied to an axle and thereby turns a wheel. In each of these vehicles the wheel and axle is used to multiply speed.

Simple machines can change the direction of a force. A fixed pulley is a good example of this kind of machine.



You have found out, then, that a simple machine is a tool which can *multiply a force, multiply speed, and change the direction of a force.*

You must have used at least one simple machine today. Perhaps it was a lever, an inclined plane, a wheel and axle, or maybe it was a pulley.

Have you used a doorknob? a faucet? some scissors? shop tools? steps? a window shade? a light switch? a radio knob? or even your arms and legs? Do any of these contain simple machines? Yes, they all do, but this is just the beginning.

You probably realize by now that simple machines can also be found in larger, more complicated machines, such as the automobile or bicycle. On the automobile, for example, the door handles, accelerator pedal, window cranks, gear shift, and directional signal switch are all forms of simple machines. As you read on, you will see why.

But first, what about your bicycle? How many simple machines does it contain? You already know about the wheels. What about the pedals? or the handlebar?

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A simple machine can
 - a. multiply a force
 - b. make a force
2. A single fixed pulley is a simple machine that can do which one of these things:
 - a. multiply force
 - b. move from place to place
 - c. change the direction of a force
3. The rear wheel of a bicycle is a simple machine that can do which two of these three things:
 - a. multiply a force
 - b. multiply speed
 - c. move from place to place

B. Write a paragraph or two on this topic: How Can Simple Machines Help Us to Do Work?

**USING WHAT
YOU KNOW**



1. In your home, you probably have either window shades or venetian blinds. Can you think of any simple machines that would be used with either? A careful investigation should give you a clue.
2. What kind of machine is being used in the picture? ■

ON YOUR OWN

Set up an inclined plane, as you did in the investigation on page 155; but move the board so that about one-fourth of it is sticking up over the books.

Will you need to apply more force to pull the skate up the board in this new position?

2. The Levers You Use

Today, you may have used a pair of scissors, pried open a can with a screwdriver, or opened a big packing box with a crowbar. You may have cracked a nut or pruned a branch from a tree.

If you have ever pried the lid from a paint can with a screwdriver, you probably gave no thought to the matter. You just put one end of the screwdriver under the lid, pushed down on the other end, and up came the lid. Have you ever wondered why you used the screwdriver in the first place? Think about it now and see if you know the advantage in using one.

In each case, you would have used a lever. A lever is an important simple machine. How you use it is even more important. Knowing where to put the fulcrum is most important of all.

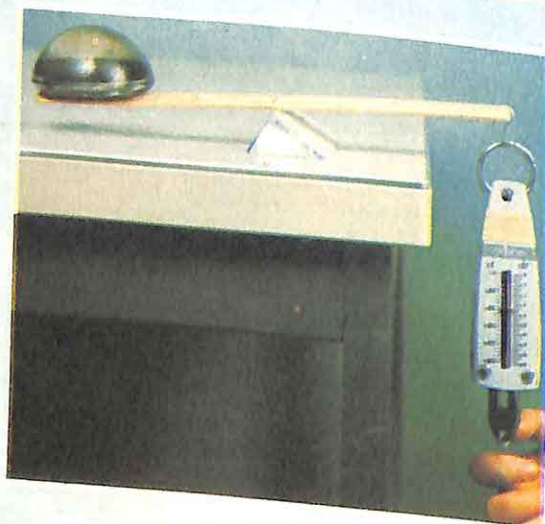
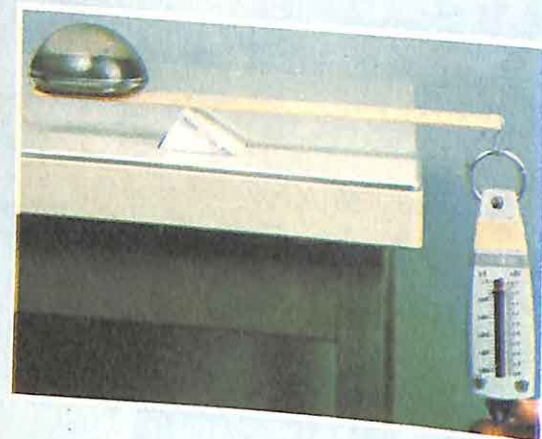
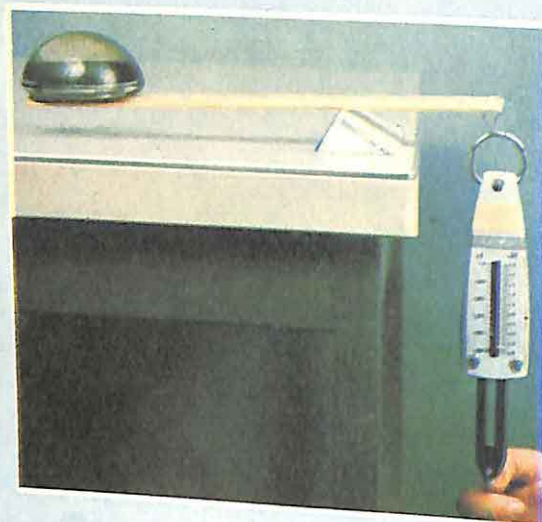
Look at the diagram below. Notice the position of the fulcrum. The distance from the **effort** to the fulcrum is much greater than the distance from the fulcrum to the **load**. What is the advantage of this arrangement? Suppose the load and effort were reversed. Do you know any situations in which it would be an advantage to have the effort nearer the fulcrum?



It is easy to recognize that a seesaw is a kind of lever. The smaller child is using one to help him lift the larger boy.▲ If he is to succeed, where should the fulcrum be placed? Where in the pictures is the effort being applied? Which of the boys is the load?

We live with and use many kinds of levers every day and there are basic principles or rules that all levers follow. For instance, there are only three things to consider—the load, the effort, and the fulcrum, and there are only three different ways they can be arranged. To understand why this is true, start with the investigation on the next page. From there you can look next at all levers.

AN INVESTIGATION into the Location of the Fulcrum



Needed: a weight to be lifted (a paper-weight will do); a ruler or yardstick; a support to act as a fulcrum; and a spring balance

Since there are so many levers everywhere, you can investigate them either at home or at school.

Make a fulcrum by cutting a small box top diagonally, as shown in the picture; use a ruler or yardstick as the lever itself.

Place the weight to be lifted on the lever with the fulcrum placed first in the position shown. ■ Notice that the fulcrum is near the point where you apply the force, as you pull down on the ruler (the lever). Lift the weight on the lever, using the spring balance, as shown. Then find out what the difference will be if the fulcrum is placed somewhere else. Try placing the fulcrum under the ruler in a position near the object to be lifted. ● The object to be lifted by the lever is called the load. Now lift the load again. Are the results the same as they were the first time? Are they the same as those in the picture? How do you account for the difference?

Try lifting the load with the fulcrum placed near the middle of the lever. ▲ What are your results?

In which of the positions of the fulcrum did it take the least effort to lift the load?

A Problem—Finding the Fulcrum

Scientists use a special name for the force applied to a simple machine; it is called the **effort**. The place where you push or pull on a lever is the point where the effort is applied.

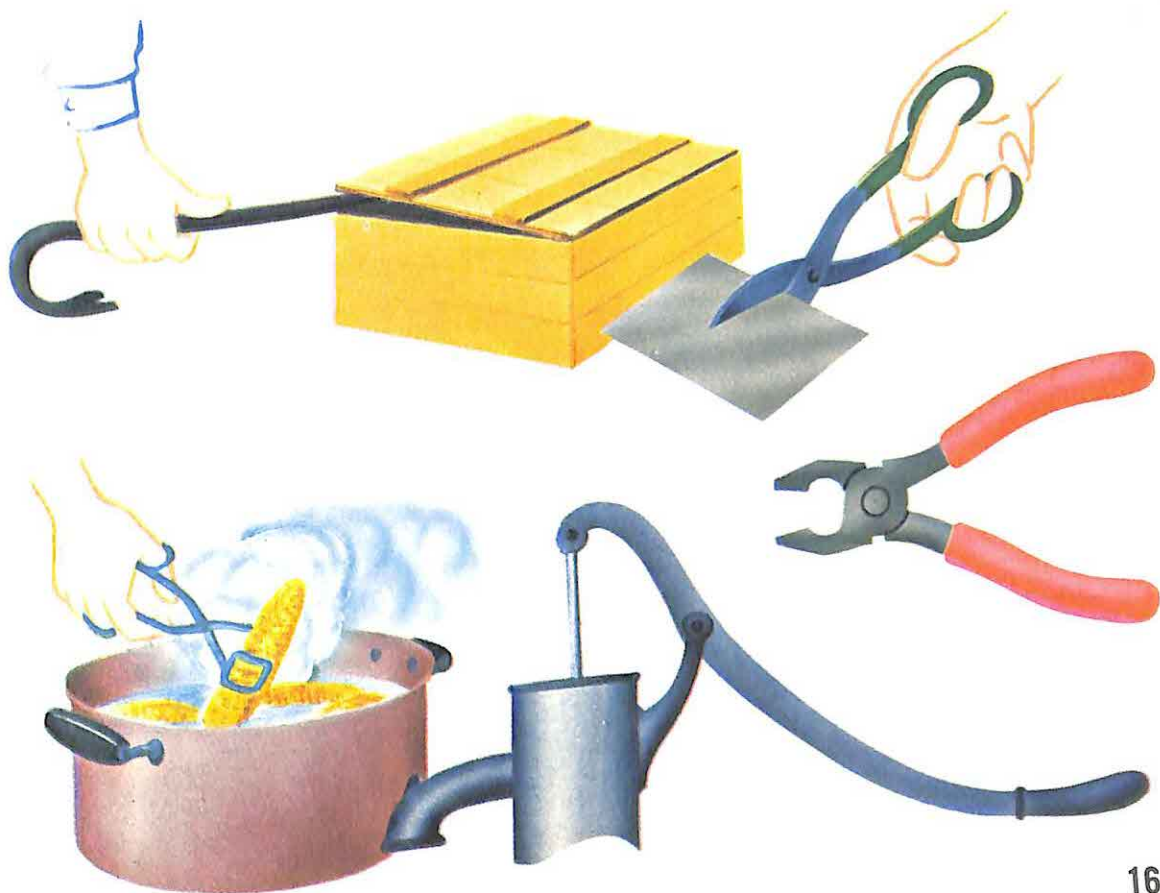
A load can be moved most easily when the fulcrum is *farthest* from the place where the effort is applied. A lever set up this way is the best for multiplying a force.

Examine two types of pruning shears, one with long handles, the other with short handles. Examine different kinds of scissors. In what ways are they different? Why do you think they are different? How are

shears and scissors alike? Shears and scissors contain two levers that are fastened together and share a single fulcrum. Which kind of shears would be best for cutting a thick twig, the one with long handles or the one with short handles? Can you explain your answer in terms of levers?

Clearly a lever can be very useful to us if we know where to place the fulcrum and where to apply the effort. Study each one of the levers in the picture, and for each one find the following three things: ■

- the load
- the fulcrum
- the best point to apply effort



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

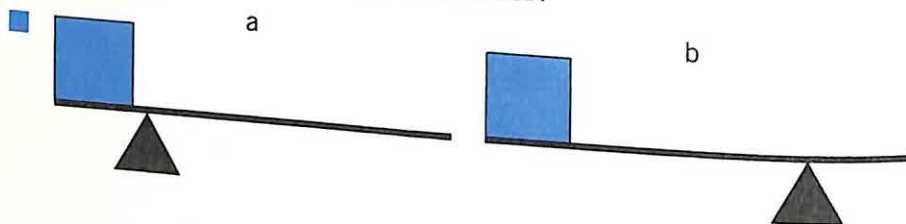
1. One of the following is not likely to be used as a lever. It is a

- a. seesaw b. screw c. crowbar

2. A load can be moved most easily when the fulcrum is located at a certain point in relation to where the effort is applied. That point is

- a. nearest to the effort b. farthest from the effort

3. Where should the fulcrum be placed for ease in lifting the load in the picture? ■ How does the position of the fulcrum affect the usefulness of a lever?



B. Write a paragraph or two on this topic: How Levers Help to Do Work.

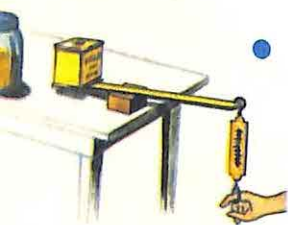
ON YOUR OWN

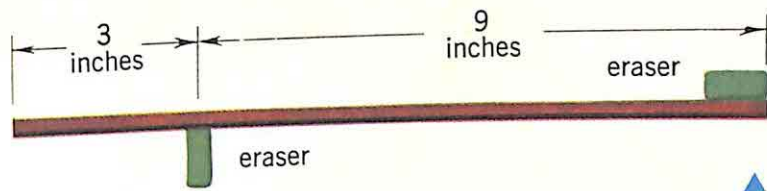
A. Try This Investigation

Set up a lever like the one shown in the diagram. ● You will need a pint milk carton, some sand or soil, a wide ruler to be used as a lever, a spring balance, and perhaps a wooden block as the fulcrum. Use the carton filled with sand as your load. You can apply an effort to lift the load by pulling down on the lever.

If you change the weight of the load by adding or pouring out sand, there will also be a change in the amount of effort you have to use.

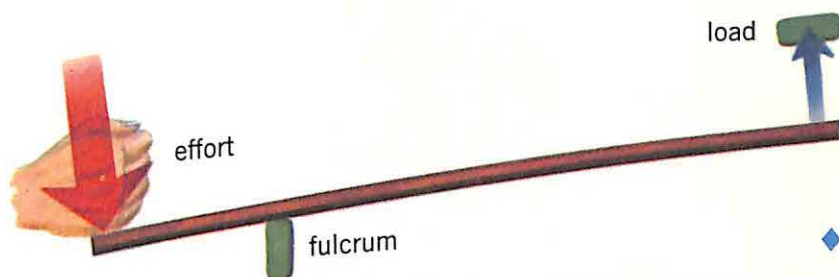
Try to find out whether the change in effort corresponds in any way to the change in load. You can weigh the load each time by using your spring balance. Write down your results after each trial.





B. Try This Investigation

Make a catapult (kat'ə-pult) with a ruler and two erasers. ▲
 When you pound your fist down on the short end of the lever,
 the load shoots up with great speed. ♦ Can you explain why?
 Which force do you think is greater, the effort or the load?

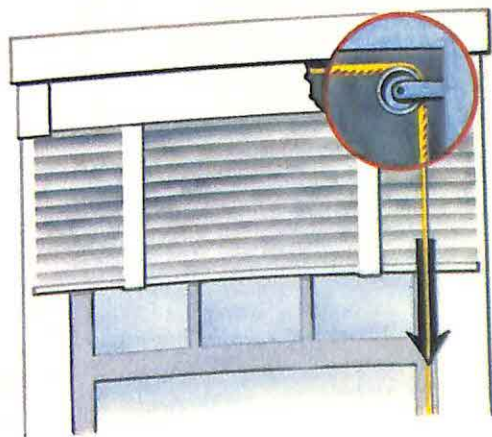
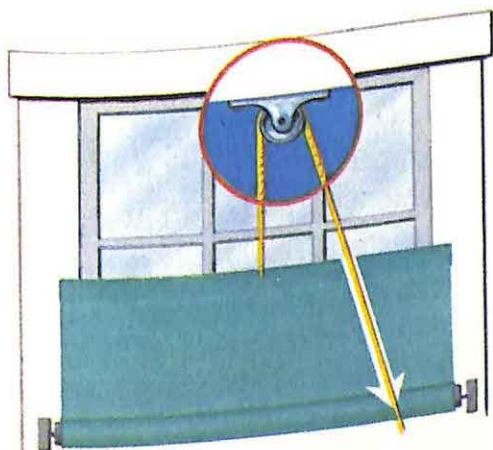


3. Uses of Pulleys

Perhaps your classroom has shades which can be pulled up and down with a cord or it may have venetian blinds. You may have wondered how

they are moved up or down. If you could look inside the box at the top of the blinds, you would find a pulley. ★

If you have ever lived on a farm or visited one you may have seen pulleys being used. Imagine carrying a large





bag of feed up a ladder into the loft. It would be difficult to do without help, and the best help is from a machine.

Bags of feed are often lifted as shown in the picture. ■ The load moves *up* as the effort is applied *downward*. The effort applied must be as great as the weight of the feed. The fixed pulley changes *only* the direction of the effort, making it more convenient for the person who is doing the work. It does not multiply the effort he applies.

Fixed pulleys make it more convenient to do many tasks. You can use them to help hang out the wash or to lift the sail on a sailboat. A fixed pulley changes the direction of the pull; but this is not all that pulleys can do. The investigation on the opposite page shows more about the uses of pulleys.

Lifting an Iron Beam or Piano

It is not easy to lift a piano to the top floor of a building, but there are several ways that it can be done. The piano can be carried up in an elevator, if the elevator is large enough; or it can be lifted up with a combination of fixed and movable pulleys. When fixed and movable pulleys are used together, the system is called a **block and tackle**. What is the advantage of combining pulleys in this way? A single fixed pulley only changes the direction of the effort. What does a movable pulley do? Investigate to find out the purpose of a block and tackle.

AN INVESTIGATION into the Use of a Pulley

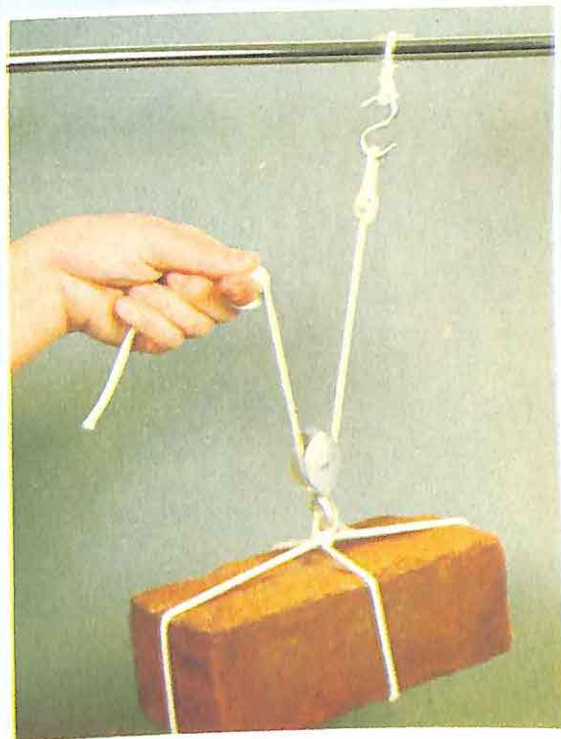
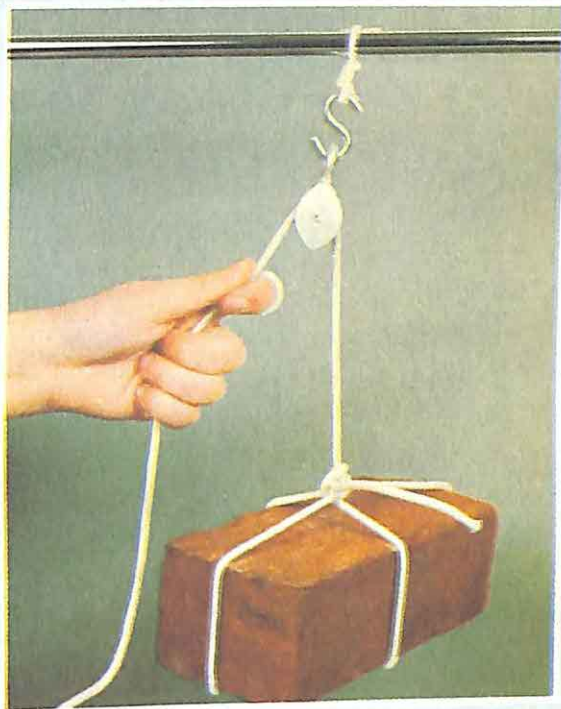
Needed: some heavy cord; several bricks; some small pulleys

Tie a heavy cord around a brick, and lift it with one finger. It is not very easy to do. *Be careful not to lift the brick directly above anyone's feet, in case it should fall.* The cord will probably squeeze your finger.

Obtain some small pulleys or make them out of empty thread spools, wire, and nails. Fasten one of the pulleys to a solid support, such as an overhead bar, or to a hook on the wall. Place the string over the pulley and lift the brick. ■ Is it easier this way? Or is it really true that a fixed pulley only changes the direction of a force?

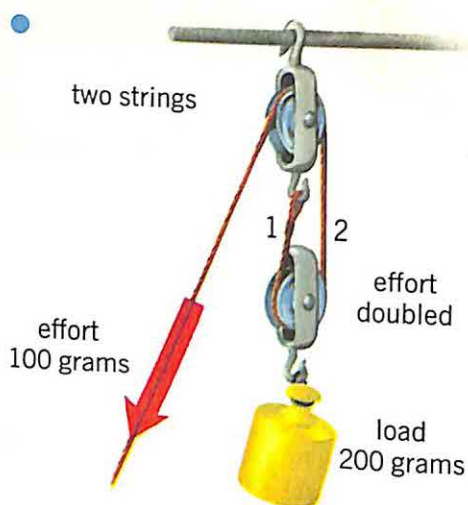
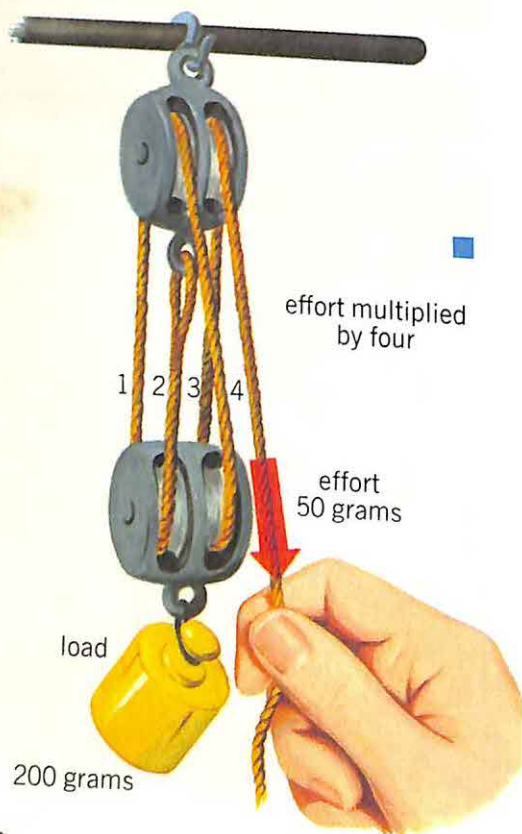
Another type of pulley you can try is called a **movable pulley**. Attach a movable pulley, like the one shown in the picture, to your load. ● Tie one end of the cord to the fixed support and lift the same load by pulling up on the other end of the string. Does lifting the brick seem any easier now? Is a movable pulley another simple machine that can multiply the effort you apply?

Additional Investigation: Repeat the investigation above, but this time use a smaller weight and a spring balance to measure the effort. How many times does the movable pulley multiply the effort?



Examine the block and tackle in the picture. ■ A block consists of a pulley wheel or of several pulley wheels in a frame. Each of the blocks shown in the illustration contains two pulley wheels. Notice that one block is fixed, while the other is movable. A block and tackle is usually a pair of pulley blocks.

The number of lines running through the pulleys is very important. In the block and tackle shown in the illustration there are four such lines. It is possible for one man to lift a heavy beam with a block and tackle of this type. How can he do it? You can find out by doing the investigation on the opposite page. It shows



how to make and use a small model of the larger block and tackle used by workmen.

An Explanation

What is the difference between the two pulley systems shown on this page? Study them carefully. Observe that one has two strings supporting the movable pulley; the other has four.

With two strings, an effort of only 100 grams was applied to lift a load of 200 grams. ● Each string supported 100 grams, or one-half the load of 200 grams. Therefore with two strings, you could lift 200 grams (2×100) with only 100 grams of effort. The third string coming off the fixed pulley merely changed the direction of the effort.

With four strings supporting the movable pulley block, an effort of only 50 grams can be applied to lift a load of 200 grams. Each string supports a weight of 50 grams. The fifth string changes the direction. ■

AN INVESTIGATION into Using a Block and Tackle

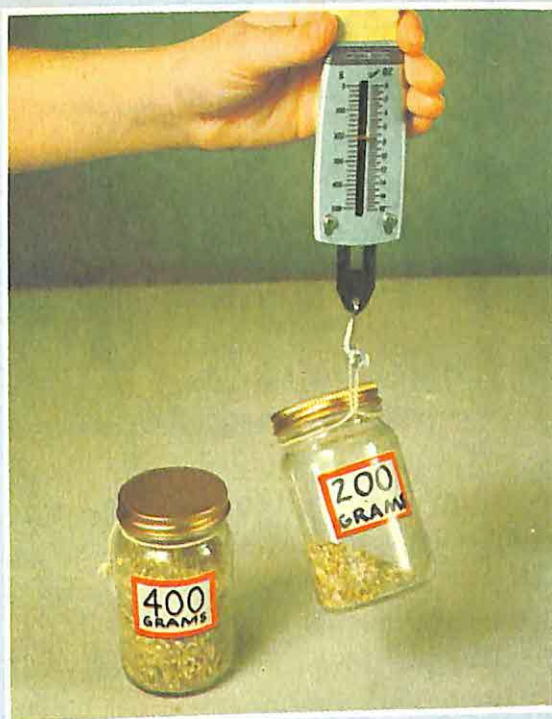
Needed: a set of small weights; a spring balance; two single and two double pulley blocks; several feet of string

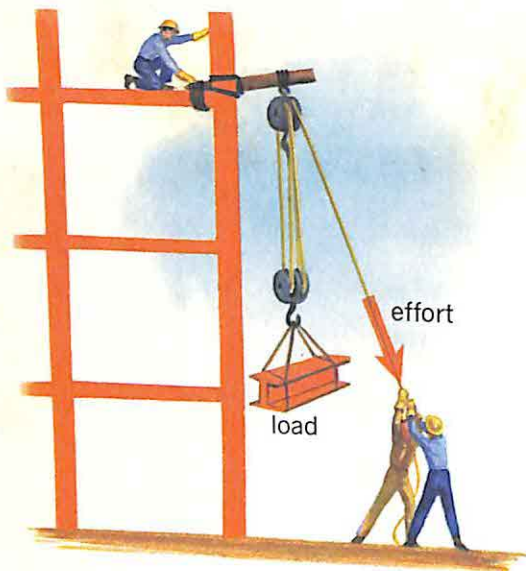
If you cannot obtain a set of small weights, you can make your own by pouring different amounts of sand into several small jars or plastic bags. Weigh them with your spring balance, and label each one with its correct weight. ■ The group of students that did this investigation weighed their sand in **grams**, which is the basic unit of weight in the **metric system** (454 grams are equal to one pound). You may use the system you prefer, the English or the metric.

Set up the two single pulley blocks, as shown on the opposite page. This makes a block and tackle with one fixed pulley and one movable pulley.

How many grams of effort are needed to lift a 200-gram load with this block and tackle?

Now set up the double pulley blocks, as shown. ● The block and tackle in the picture is a model of the one the worker used to lift the steel beam. Lift the same 200-gram load with the double pulleys. How many grams of effort do you need now? (The students found they needed only 50 grams.) Why is less effort needed with the second pulley than with the first? After all, the load is the same in each case. What makes the difference?





3. The greater the number of strings lifting the load, the more the effort is multiplied.

Which of these is true? The group of students performing the investigation marked 1 and 3. Do you agree?

A Problem

You might see a block and tackle like that in the picture almost any place where construction is going on. Study the block and tackle shown lifting the beam. ■ How many ropes are between the pulleys? If the beam weighs 1,000 pounds, how many pounds of effort must be applied to lift the beam?

Since the four ropes together support a load of 1,000 pounds, each rope, by itself, supports 250 pounds, or one-fourth of the load. A force of 250 pounds then could be used to lift the weight. The simple machine therefore multiplied the effort by 4 (250 pounds $\times$ 4 = 1,000 pounds.)

Here is a problem which you can now figure out for yourself. See if you can find out why the effort in the picture should be 100 grams. ● Ask yourself these questions:

What is the load?
(500 grams + 100 grams = 600 grams)

How many ropes support the load?
(six ropes)

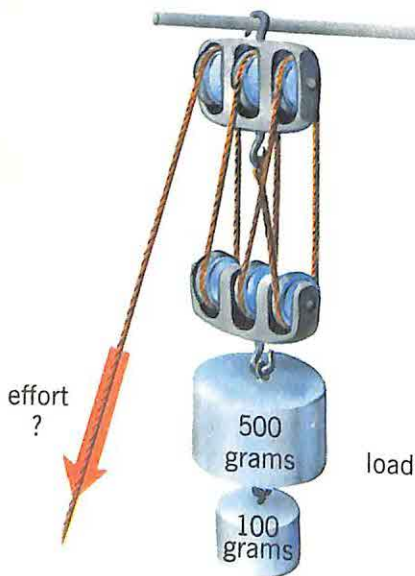
What is the effort? Why?

How many times did the machine multiply the effort?

Study the results of your investigation once again and see if you can answer this question: Which of these three statements is correct?

1. The fewer the number of strings used, the greater must be the effort applied.

2. The fewer the number of strings lifting the load, the more the effort is multiplied.



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

All of the statements below are made about pulleys.

1. When the number of strings lifting a load is decreased, the load is
 - a. lifted more easily
 - b. harder to lift
2. When the number of strings lifting the same load is increased, the effort needed is
 - a. less
 - b. greater
3. To lift a greater load with the same amount of effort, we would
 - a. increase the number of strings
 - b. decrease the number of strings

B. Write a paragraph or two on this topic: Pulleys.

ON YOUR OWN

A. Using a weight, a spring balance, and pulleys, like those in the investigation on page 169, see if you can find the answer to this question:

What distance must you pull the string as you lift a load with a block and tackle?

You can start with a block and tackle with four strings to lift the load. Measure the length of string you must pull in order to raise the load a distance of 1 foot.

Then use a block and tackle with two strings between the pulleys. Again lift the weight 1 foot. What length of string must you pull to lift the load now?

What is your conclusion?

B. In the Library

1 pound = 454 grams

? = 1,000 grams (1 kilogram)

Finish the table. Then consult a dictionary or encyclopedia to find out about the metric system.

4. Other Machines You Use

Do you recognize a simple machine in the picture below? ■ Can you tell what kind it is?

First imagine a road going up a hill. It is the same as the ramp that Andrew's father built for him, so that he could wheel the chair up into the house with less effort. Since a road up a hill is really an inclined plane, part of the weight of the object being moved up the hill will be supported by the sloping road.

A road going up a hill multiplies the effort applied to move the load to the top of the hill. The principle is the same as that found in the investigation on page 155.

The ramp shown in the picture below winds around and around. It goes up and around to the observation tower. The winding ramp is an in-

clined plane also. It is a winding, or spiral, inclined plane. A road winding up the side of a mountain is also.

It is possible for heavy-duty trucks to move up the side of a mountain on a winding road. The more times the road winds around the mountain, the more gradual is the slope, or incline. The gentler the slope, the less effort it takes to get up the mountain. But, remember one thing, the distance that the truck travels is increased as the effort is decreased. This is an important principle of simple machines. What other kinds of winding inclined planes do you know about?

There is another kind of winding inclined plane that is used very often in your home. Can you guess what it is? It is the screw. You can find out more about the screw as a simple machine by doing the investigation on the opposite page.



AN INVESTIGATION into a Winding Inclined Plane

Needed: a sheet of paper; a pair of scissors; a pencil; a piece of wood; a screw; a screwdriver

Cut an inclined plane out of paper. Make it 12 inches long and 6 inches high (as in the photograph) and wind it around a pencil. ■ Does it remind you of the **threads** on a screw?

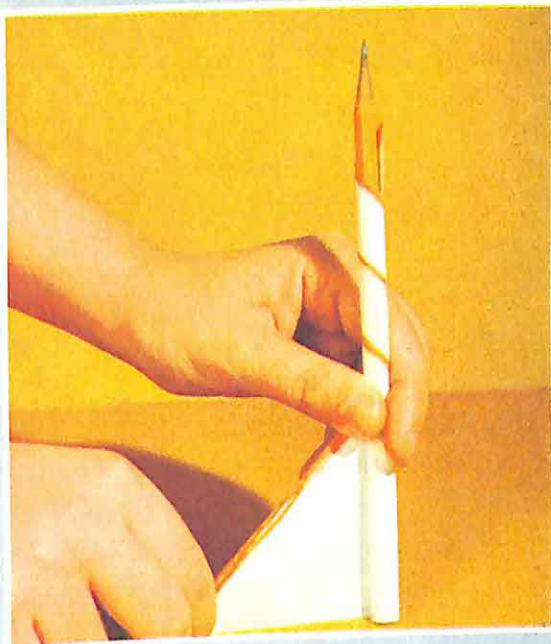
Examine a screw closely, perhaps with a magnifying glass. ● Trace the winding plane around the screw and up to the pointed tip.

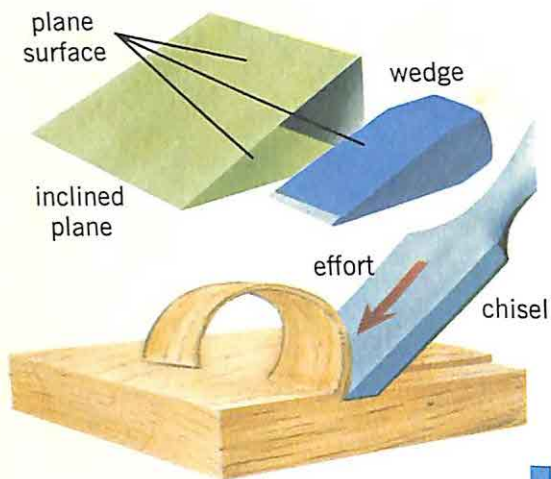
Turn the screw into a piece of wood with a screwdriver. When the screw is half way into the wood, stop turning and try to push it in the rest of the way with the screwdriver. Is it easier to push the screw straight in or is it easier to turn the screw into the wood? When the screw is turned, its point is pushed ahead with greater force.

Has the turning screw helped to increase the force of your wrist? The screw is another simple machine that can multiply a force.

Is the screwdriver also a simple machine? If so, what kind?

Fasten two pieces of wood together with a screw and then try to pry them apart. You will probably find this difficult to do, much more so than if the pieces were held together only by a nail. The screw multiplies the force which binds the pieces of wood together.





Still Another Simple Machine

An inclined plane slants up from a point. Cut two long planes, such as those shown in the diagram, and put them together. ■ By doing so, you have made another form of inclined plane called a **wedge**.

If you have a chisel or a screwdriver, look at the tip where two plane surfaces come together, forming a wedge. When a chisel is forced into a piece of wood, its sharp edge goes between the grains of wood easily and pries the wood apart.

Once the sharp edge of a wedge is forced into any object, it can split the object apart.

As the effort moves the wedge forward it pushes sideways against the grain of the wood. This happens because the greater thickness of the wedge exerts greater force as it moves into the grain. The wedge therefore changes the direction of motion. In what other way does the wedge act as a simple machine? Does it multiply effort? Does it multiply speed?

A wedge greatly multiplies force. It can do work that might be impossible if you used only your muscle. A wedge is one more simple machine which multiplies force.

What other wedges have you used? Have you used a hatchet to split wood? A snowplow is also a wedge, as is a plow that turns over the soil.

If you look about your home, you should find many kinds of inclined planes. How about the knives in the kitchen? Are they inclined planes?

Can you think of a wedge that is a different shape? Some wedges do not have a straight edge at all. Instead they are round and have a sharp point. Think of a nail, for example. Does it act like a wedge? When a nail is forced into a piece of wood, the effort (which is forward) causes the nail to push sideways, separating the wood so it can enter.

There are many other round wedges. A needle is a round wedge, is it not? What about a pin, or a knitting needle, or a bullet, or the nose cone of a rocket? Perhaps you can think of some more.

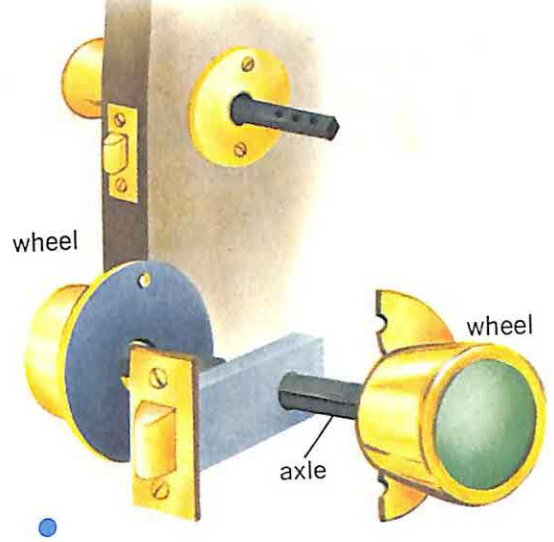
Since round wedges are very much like screws, many people have trouble telling them apart. How is a round wedge different from a screw? Think about the way in which the effort is applied. A nail, or round wedge, is pushed forward into a piece of wood. The direction of the effort is straight and forward. A screw, remember, is turned. The effort rotates the screw as it moves forward into the wood.

Doorknobs as Simple Machines

Every time you open a door you use a simple machine. Remove the knob from a door, as shown in the picture, and try to open the door. ● It is not easy to turn the axle without the help of the knob.

The doorknob is another example of a wheel and axle. ● The knob, really a kind of wheel, is attached to a rod or axle. When you turn the wheel fixed to the axle, you increase (or multiply) your effort greatly. The wheel and axle is a simple machine that multiplies effort when the effort is applied to the wheel. For instance, the steering wheel of an automobile is a wheel-and-axle machine. It multiplies the driver's effort so much that he can turn a car or a huge truck with very little effort.

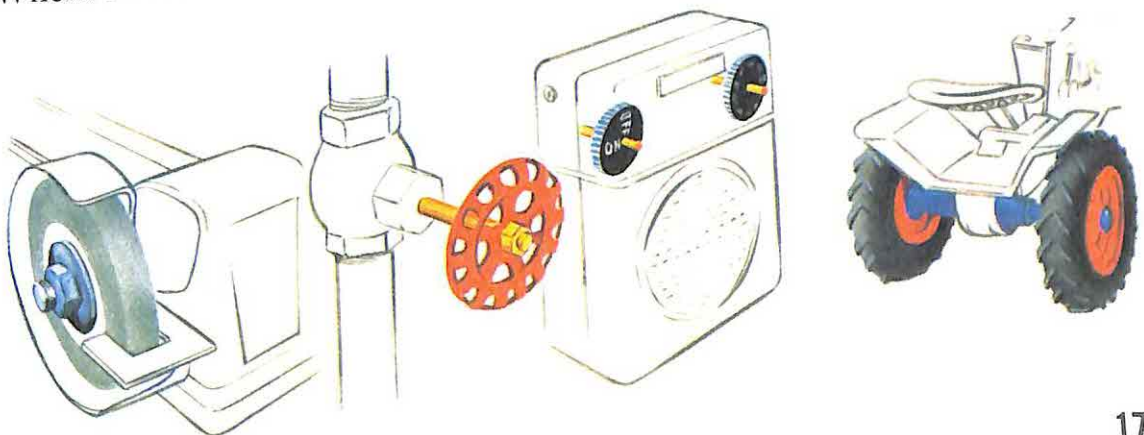
The bicycle wheel, discussed on page 158, is also a wheel and axle; but it is not used to multiply effort as is the doorknob or steering wheel. Instead, it multiplies speed. How is the bicycle wheel different? Why does it multiply speed rather than effort? Where is the effort applied?

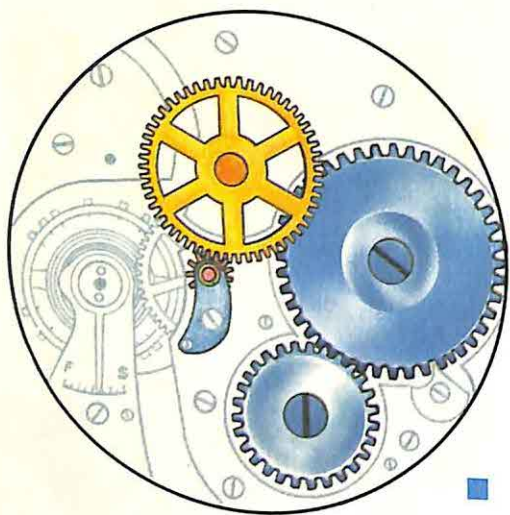


The crank on a pencil sharpener is also considered a wheel and axle; it can also multiply effort. Have you noticed that whenever you turn the crank around completely, it really outlines the shape of a wheel?

Without the machine, you might find it just as inconvenient to sharpen a pencil as to open a door.

The wheel and axle has many uses. Some examples are shown in the picture. ▲ Look at them carefully. Which are used to multiply force? Which are used to multiply speed?

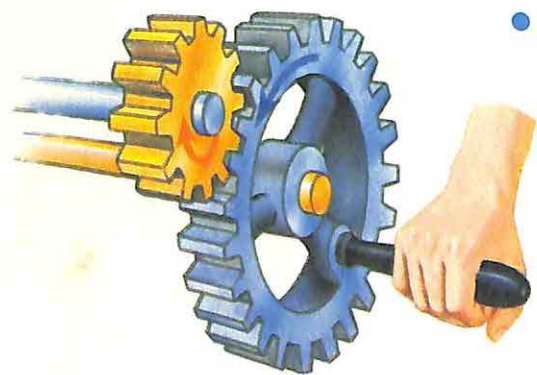




The Uses of Gears

A special form of the wheel and axle can be found inside of a watch. ■ It is the toothed wheel, commonly called a **gear wheel**. The teeth on a gear wheel make it possible for one wheel to turn another.

Study the picture to see how gear wheels can multiply speed. ● The larger gear, with 24 teeth, turns a smaller wheel which has only 12 teeth, or only half as many. The teeth of the larger gear fit into the teeth of the smaller gear, so that when the larger gear turns, the smaller gear



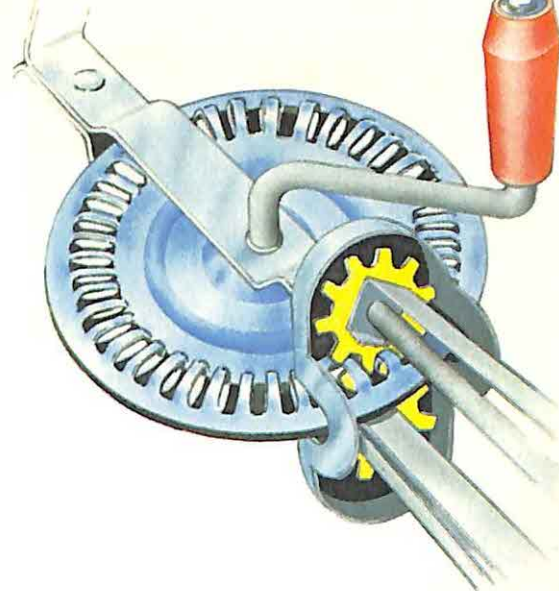
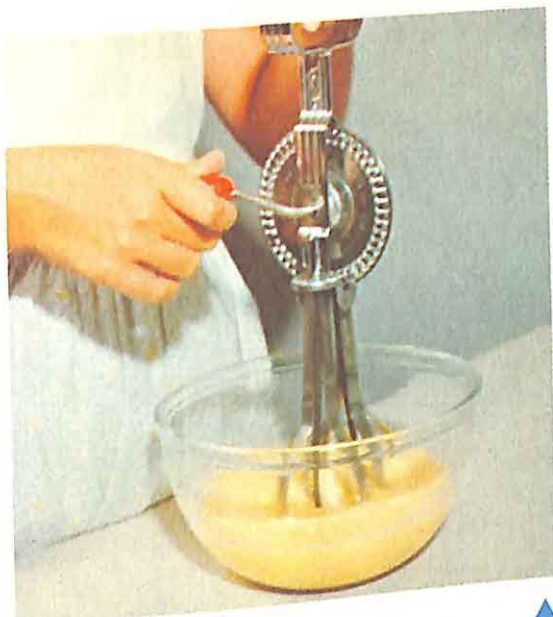
must turn as well. For each turn of the larger gear wheel, the smaller gear wheel must turn *two* times, so the smaller gear turns *twice* as fast.

Examine an eggbeater by turning the handle around once, slowly. ▲ How many times does the beater turn? Ask two classmates to count the number of turns that the beater makes while you count how many times you turn the handle. You may find that the beater makes about four turns while the handle is turned only once. Since the beaters turn more often than the handle in the same time, they are moving at a greater speed.

Count the teeth on each of the gear wheels of the eggbeater. ◆ Suppose the larger wheel has 40 teeth, and the smaller wheel has 10 teeth, or one-fourth the number of the teeth on the larger wheel. For each turn of the larger gear, how many times would the smaller gear turn? Would the answer be four?

The smaller gear turns the beater. Why does the beater turn four times faster than the handle? Do all eggbeaters have the same gear ratio?

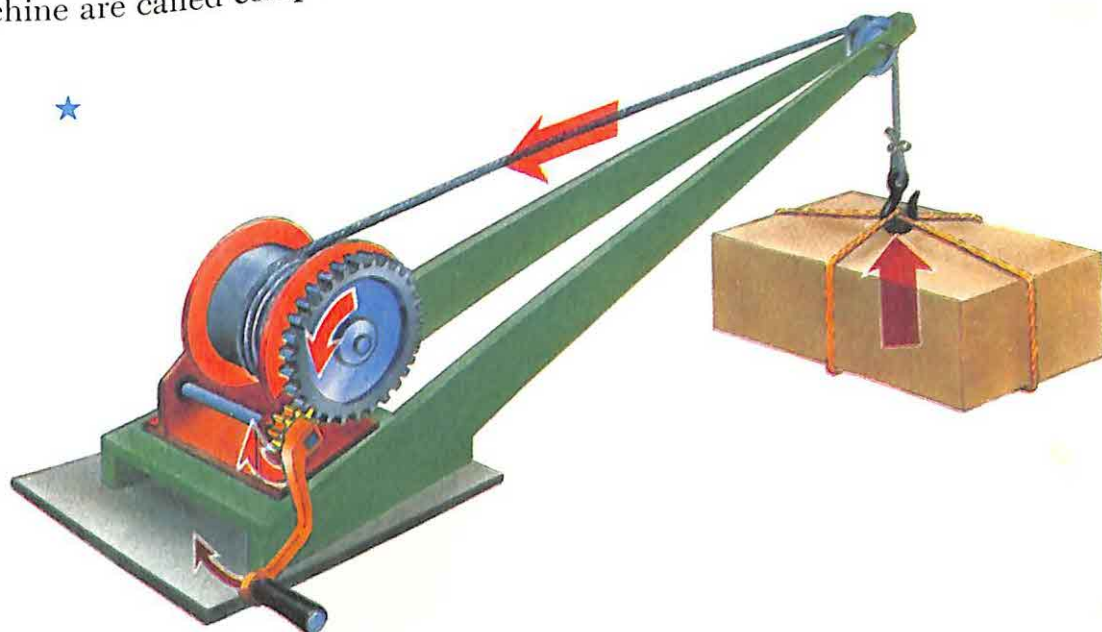
Gears are machines that can multiply speed, but they can be used in other ways, too. The picture shows a model of a hand-operated crane. ★ When a force is applied to the smaller wheel, the larger wheel is able to lift a greater load. Gear wheels, then, can also be used to multiply effort. They are a special kind of wheel and axle. Can they also be used to change the direction of a force?



Compound Machines

Many machines are made up of more than one kind of simple machine. Recall that the kinds we have been studying are: lever, pulley, wheel and axle, inclined plane, wedge, and screw. Machines containing more than one kind of simple machine are called **compound machines**.

A pair of scissors is a compound machine. It has two levers fastened together at the fulcrum, and the cutting edge on each of the blades is a wedge. Therefore all scissors, shears, and the like, are compound machines containing levers and wedges. Both the lever and the wedge are simple machines which may multiply effort.





Another compound machine is the meat grinder. The handle of a meat grinder is really part of a wheel and axle. ■ Look inside and you will find that the handle is attached to a kind of screw. ● The meat grinder, then, contains a wheel and axle that turns a screw.

Below is a list of the six basic simple machines that can be combined to form compound machines. Which of them are combined in a jack?

lever	inclined plane
pulley	wedge
wheel and axle	screw

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Two of the following which act like an inclined plane are a

- a. steep road
- b. ramp

c. nutcracker

2. One of the following contains a winding inclined plane. It is a

- a. hammer

b. meat grinder

3. A wedge acts like
 - a. a pulley
 - b. an inclined plane
 - c. a lever
4. Two of these which have gears as part of them are
 - a. a bicycle
 - b. an eggbeater
 - c. a doorknob

B. Write a paragraph or two on this topic: The Uses of Gears.

USING WHAT YOU KNOW

1. If you wanted to bind two pieces of wood together tightly, you would use a
 - a. nail
 - b. screw

Why?

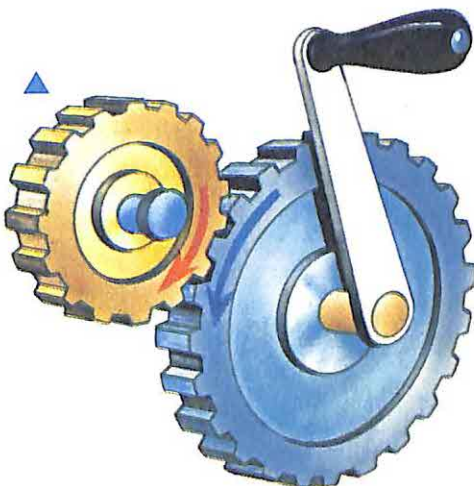
2. Which of these have wedges as part of them?
 - a. screw
 - b. chisel
 - c. pole
 - d. knife
 - e. axe
 - f. nail

ON YOUR OWN

In the Laboratory

Cut two gears out of cardboard which have the same number of teeth as those shown in the picture.▲ Be certain to fix the gears so that the teeth fit each other (that is, so that they mesh).

Suppose the smaller of the gears is connected to an axle that is connected to a wheel, as shown in the picture. Then answer the following questions:



1. For each complete movement of the larger gear, how many times does the smaller gear move?

2. If the small gear were made even smaller, would the wheel attached to it move faster or slower? Why?

3. Make several other combinations of gear wheels, for example, one that multiplies speed by 3, or multiplies force by $2\frac{1}{2}$.

5. A Resisting Force

Do you live in a part of the country where you can ice-skate? If so, you may have sometimes wished that the ice were not so smooth, so that you could glide more slowly. Why do you glide so smoothly on ice?

The sharp edges of the skate blade are really wedges, simple machines. This kind of machine bites into the ice and helps to keep you from skidding sideways, yet a push sends you forward. If you were to spread sand on the ice, what would be the action of the sand? The investigation on the opposite page will give you some clues.

The Force of Friction

Why is it harder to pull the block over the rough surface of the sandpaper? Each time you pull the piece of wood across the table, your work is made harder by **friction**. Friction is a force that resists motion. It is caused by two surfaces rubbing against each other. *The amount of friction depends on the types of surfaces that are rubbing against each other.* Since the sur-



face of the sandpaper is rougher than the surface of the tabletop, it causes more friction. It is harder to pull the piece of wood across the sandpaper because the force of friction is greater.

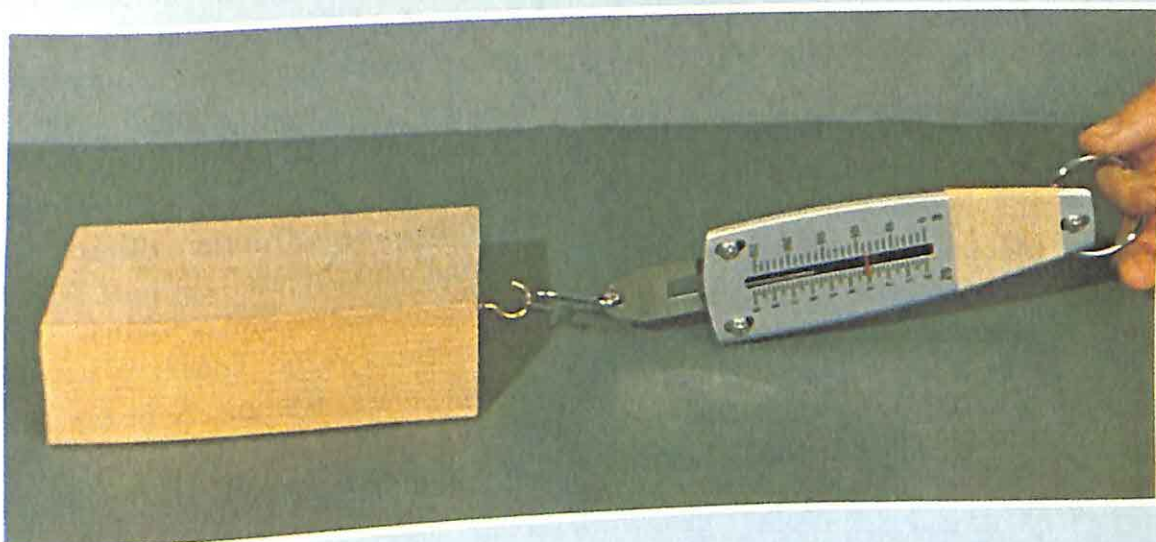
Why is it harder to pull two blocks across the top of the table than to pull just one? It takes more force because the extra weight makes the bottom piece of wood press harder against the surface of the table. The force of friction is greater.

Why does the can move farther when it is rolling than when it is sliding? It moves farther because there is less friction to slow it down. Remember, friction is caused by two surfaces rubbing against each other. When surfaces are rolling they do not rub against each other as much. Let us see why.

Place a finger into the open end of a juice can (be sure there are no sharp edges) and rest it gently on the palm of your hand. Move the hand under the can forward, as shown. ■ Look at the two touching surfaces. Notice that the surface of the can moves in the same direction as the surface of your hand. Now move the hand under the can back toward you. The surface of the can moves with your hand. The surface of the can always moves in the same direction as the surface of your hand. The surfaces are *moving with* each other more than they are *rubbing against* each other.

This is similar to what happened when the can rolled along the tabletop. There is less friction because

AN INVESTIGATION into the Force of Friction



Needed: a piece of wood; a spring balance; several sheets of sandpaper; some wax paper; machine oil; a sheet of aluminum foil; an empty juice can

Pull a piece of wood across the top of a table with a spring balance, as shown. ■
What does the scale read?

Now place another piece of wood on top of the first and pull both pieces across with the spring balance. What does the scale read now? Is a greater force needed? Why?

Place several sheets of sandpaper on the table, with the rough surface up. Pull the piece of wood across the sandpaper. What does the scale read?

Now, put some wax paper or a sheet of aluminum foil on the table. Spread some oil on the paper or on the aluminum foil. Pull the single piece of wood

across again. Does this take more or less force than at first?

Place an empty tin can upright on the tabletop. A juice can will be fine. Give it a push. How far does it slide? Turn it on its side and push it again, so that it rolls across the tabletop. Does the can go farther when it is rolling than it did when it was sliding? Why?

Additional Investigation: A transfer of energy takes place as a result of friction. Several kinds of energy, such as heat energy, light energy, and sound energy can result from the mechanical energy involved in friction.

Try rubbing your hands together rapidly. What kind of energy results? What kind of energy results from rubbing a violin bow against the strings or by striking a piece of flint against a steel file?

there is less rubbing of the two surfaces against each other. Friction can be greatly reduced by using rollers.

One of man's inventions takes advantage of a rolling surface to reduce friction. Some people think it is man's greatest invention. It is the wheel, of course! Friction increases the amount of effort needed, but the wheel reduces friction.

Strangely enough, we sometimes do not want to reduce friction. There are even times when we want to increase it. Often we do not want wheels to move easily. Can you think of such a case?

Imagine an icy road. What can be done to make it less hazardous? Sand is spread on the ice to increase the friction as wheels press on the road. Sometimes it is important to increase friction to prevent accidents.

What happens when ice freezes on a sidewalk? Sand and gravel are spread to increase friction; otherwise, someone may slip and get hurt when he falls. What happens when one walks on a waxed floor? A waxed floor decreases friction. A heavy rug on a waxed floor increases friction.

Friction retards motion; in so doing, it sometimes saves lives.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Of the following two surfaces, the one which increases friction is a
 - a. wet road
 - b. dry road
2. Of the two surfaces named below, the one which decreases friction is a
 - a. linoleum floor
 - b. cement floor
3. Which of the three things listed below would reduce friction most on a dry road?
 - a. a sled
 - b. a wagon
 - c. a flat board
4. The friction produced by pulling a wooden box across a floor is greater when the box is
 - a. full
 - b. empty

B. Write a paragraph or two on this topic: The Importance of Friction.

USING WHAT YOU KNOW

Some colonists wanted to move some large logs. They had no wagons or animals. They had the large logs (which could be lifted only with great difficulty), and they also had some small logs.

Invent a way the large logs could be moved with the help of the small logs, if only for a short distance.

ON YOUR OWN In the Classroom or Laboratory

A. You can show (as in the investigation on page 181) that force is needed to overcome the force of friction.

B. Plan a demonstration to show others in the class that friction between two surfaces produces heat. Then determine a way to show that the greater the friction between two surfaces, the greater is the heat produced.

6. Is More Work Done?

Can a simple machine help you to do more work? This is a very important question. What is your answer now, before reading ahead?

Recall that simple machines may be used to multiply force. They can also multiply speed or change the direction of a force. From this you might reason that a simple machine can decrease the amount of work to be done. Before you decide, you will need to do some more investigating.

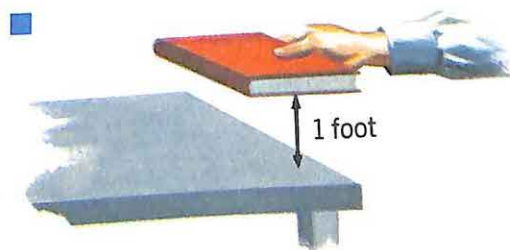
A New Concept of Work

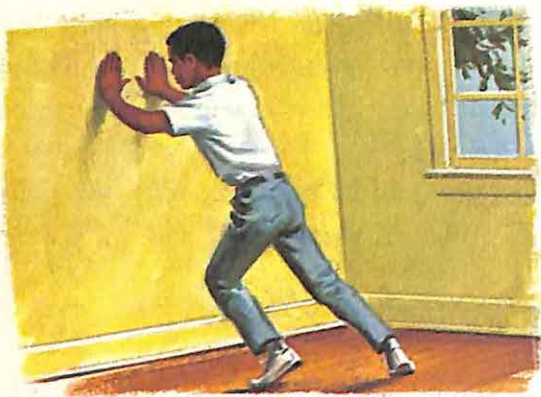
Pick up a book from the table and lift it about a foot or more. ■ The scientist would say you have done some **work**. You have lifted an object through a distance. If you push the

book across the table, you have also done work. *You have moved an object through a distance.*

When you push a lawn mower, you are doing work. When you walk, you are still doing work. When you lift anything or move anything, you are doing work.

Look up the word "work" in the dictionary. You will find many meanings listed for this important word. A scientist, however, is very careful to use a word in *one* way only. He must be sure that when he uses the





word, it will mean the same thing to any other scientist, anywhere in the world. To the scientist, then, the word "work" means only one thing. Its meaning remains the same whether the scientist is German, French, Russian, Italian, or Rhodesian.

Suppose you were to push on the wall of the classroom or of your home. ■ Even if you pushed as hard as you could, and even though pushing against the wall might have made you very tired, the wall would not budge. A scientist would say you have done no work at all.

In order to do work, *you must move an object through a distance.* ●

If the object does not move, no matter how much force you use on it, you are not doing work. The object must move if work is done.

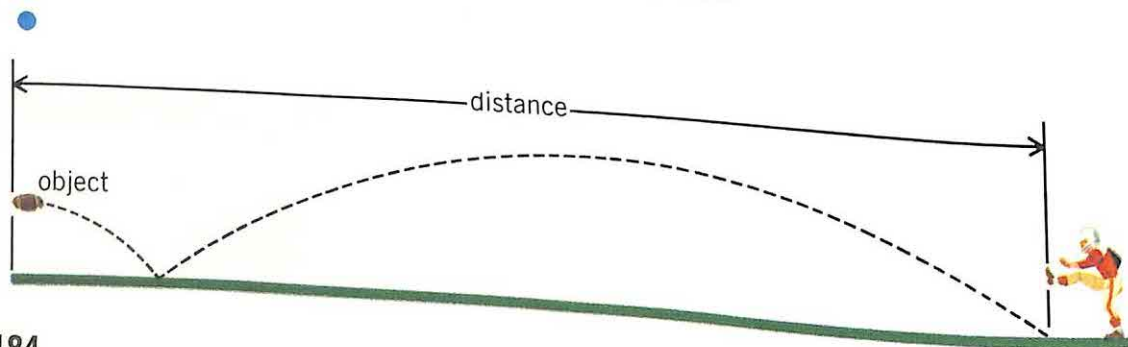
Recall that scientists deal with both concepts and tools. All concepts in science must be clearly stated and understood if they are to be used.

The scientist's concept of work is: *When an object is moved through a distance, work is done.* The scientist then uses the term "work" only as it applies to moving objects.

Man is able to do many things with the use of simple machines that he could not do without them. He can substitute the power he gets from wind, water, and other sources, for his muscle power. If you look at pictures of the pyramids of Egypt, the Grand Coulee Dam, or the skyscrapers in a city, you can see the results of using machinery.

With all the work that is being done, we are apt to think we can get more energy or work out of a machine than is put into it. What do you think?

Try the investigation on the opposite page to find out whether the simple machine, a tool, really helps you to do more work, in the way a scientist understands the concept of work. See if you can keep an accurate account of the work done as the energy is transferred from one place to another.

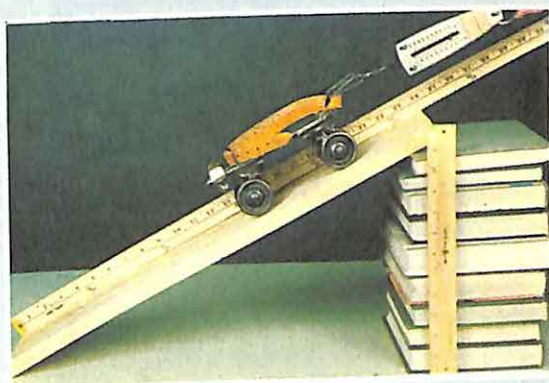
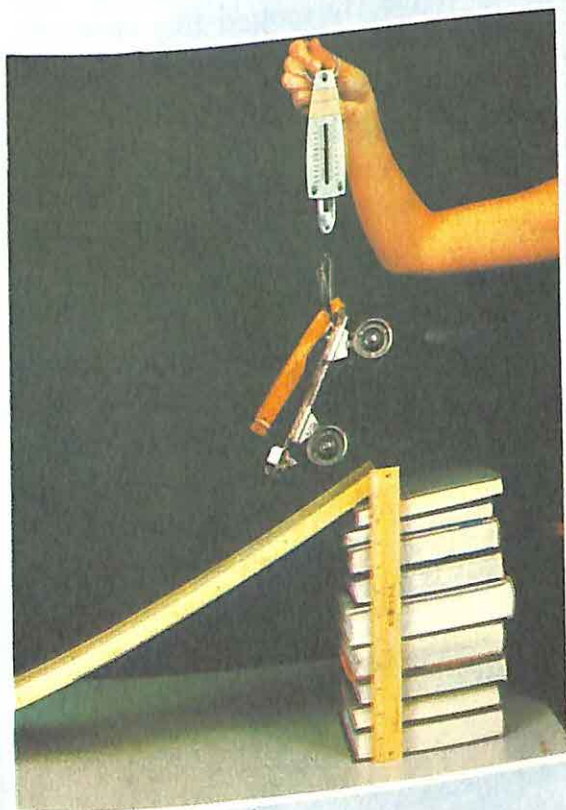


AN INVESTIGATION into How a Simple Machine Multiplies Force

Needed: a board, 2 feet long; several books; a skate; a spring balance

Prop one end of a board about 2 feet long on top of a stack of books. The elevated end should be about 1 foot above the tabletop. This simple machine was used in the investigation on page 155.

This time, lift the skate a distance of just 1 foot, as shown in the picture. ■ Look at the scale to see how much force is needed to lift the skate. Now pull the skate up the whole length of the inclined plane. You have pulled it a distance of 2 feet. ●



Does the scale read less when you pull the skate up the plane than when you lift it? Are the results about the same as before (page 155)? If so, you have confirmed your results by trying the investigation a second time. This is an important procedure in any investigation. One student found that when he lifted the skate without using the machine, the effort was 2 pounds. When he pulled the skate up the inclined plane, the effort was 1 pound. He wrote his results in his notebook. Study them carefully.

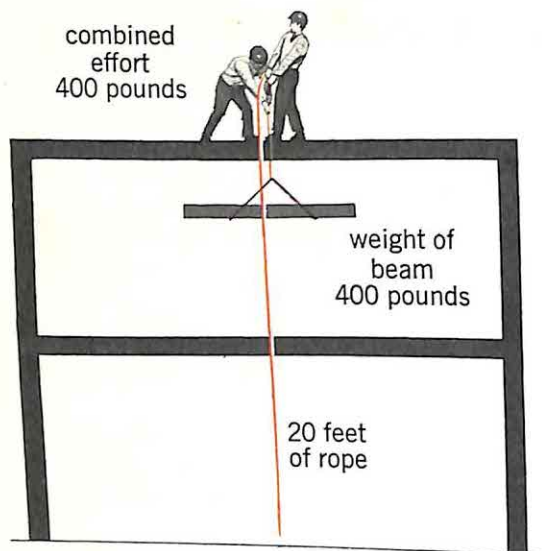
Distance skate was lifted: 1 foot

Force needed: 2 pounds (32 ounces)

Distance skate was pulled up inclined plane: 2 feet

Force needed: 1 pound (16 ounces)

Are these results similar to your own? How does the slope of the plane affect the amount of effort needed?



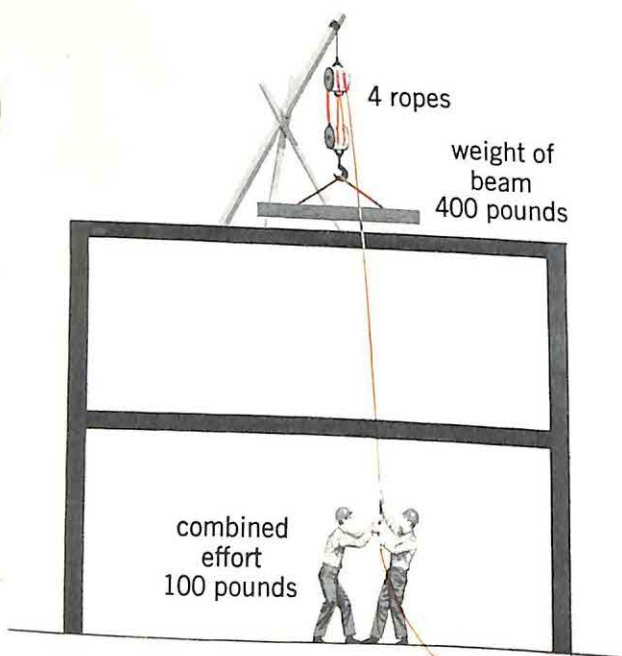
Something for Nothing?

The student found that it took less effort to pull the skate up the inclined plane than to lift it straight up. Although it took less effort to pull the skate up the inclined plane, he pulled the skate a longer distance (2 feet) than when he lifted it (1 foot). The work done was the same in each case.

Yes, it took more effort to lift the same skate straight up; but in lifting the skate straight up, he lifted it a shorter distance (1 foot) than when he pulled it along the inclined plane (2 feet).

In other words, the student moved the skate a longer distance with the machine. The machine multiplied his smaller force, but the machine did not multiply the amount of work that was done. Why? He moved the same object (the skate) a longer distance on the inclined plane than when he lifted it straight up; but the final result was that he lifted the same weight the same height. The work done was the same in each case.

He raised a weight of 2 pounds to a height of 1 foot each time. On the inclined plane, he pulled the same object twice the distance. The force (effort) was multiplied by using the inclined plane, but the student had to move the object a greater distance. The work done was the same in each case.



80 feet of rope



Another Example

Look at the picture on the opposite page of the men lifting a beam weighing 400 pounds. Suppose the men were to lift the beam straight up with just one rope. ■ Each man would then use about 200 pounds of effort. Together they would be using 400 pounds of effort.

Instead, the men decided to use a block and tackle, a simple machine. The block and tackle had four ropes, as in the picture. ■ The machine made their work much easier. Their combined effort was 100 pounds.

$$4 \text{ ropes} \times 100 \text{ pounds} = 400 \text{ pounds} \\ \text{(weight of the beam)}$$

When the men lifted the beam straight up, they applied their effort through a distance of 20 feet. With

the block and tackle, they had to move their effort through a distance of 80 feet. The distances were determined by the lengths of rope used in each case.

The machine multiplied the men's force four times, but they had to pull the rope a longer distance—four times longer than before. Their force was multiplied, but their force was applied through a greater distance. They used a smaller force over a longer distance by using the machine. They accomplished no more or less work; their work was just easier at any given moment.

The men put the same amount of work into the machine that they got out of it. They did not get something for nothing and that's a very important concept to remember.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the main concepts of this section.

1. A piano weighs 500 pounds. To lift it, four men would each need to use a force of at least
 - a. 125 pounds
 - b. 500 pounds
2. If one man used a pulley arrangement with four ropes to lift the 500-pound piano, he would need to use a force of
 - a. 500 pounds
 - b. 125 pounds
3. Suppose a man could lift about 200 pounds. Using a four-rope block and tackle, he is just barely able to lift a large piano. How much must the piano weigh?
 - a. 800 pounds
 - b. 1,000 pounds

4. In using a simple machine to lift the piano a man
- would multiply force
 - would multiply the amount of work done

B. Write a paragraph or two on this topic: Machines and Work.

USING WHAT YOU KNOW

A roofer wants to lift 100 pounds of shingles to a roof 20 feet above the ground. He is using a two-rope pulley, so his effort must be 50 pounds ($2 \text{ ropes} \times 50 \text{ pounds} = 100 \text{ pounds}$).

In lifting the shingles 20 feet, however, he uses 40 feet of rope. He pulls a length of rope (40 feet) to reach the distance (20 feet). One of the following explanations of why the roofer needs to pull 40 feet of rope is correct. Which is it?

a. A simple machine multiplies the amount of work done; therefore, the roofer should not have needed to pull twice the length of the rope. He did not know how to use the machine.

b. A machine does not multiply the amount of work done. If the machine multiplies effort, it is necessary for the effort to move through a greater distance. Since his effort was multiplied by two, he had to pull twice the distance.

ON YOUR OWN

Archimedes, a Greek (born about 287 B.C.), was probably the first person to study the mathematics of simple machines. He once boasted to his king that he could pull the biggest ship afloat into shore single-handed with the help of some simple machines.

1. Suppose Archimedes could only apply an effort of 100 pounds, while a force of 1,000 pounds was needed to move the ship. Draw a picture of a possible combination of simple machines he might have used to do this.

2. On such a machine, how far must the effort move to make the load move 10 feet?

7. The Main Concept: Energy, Machines, and Work

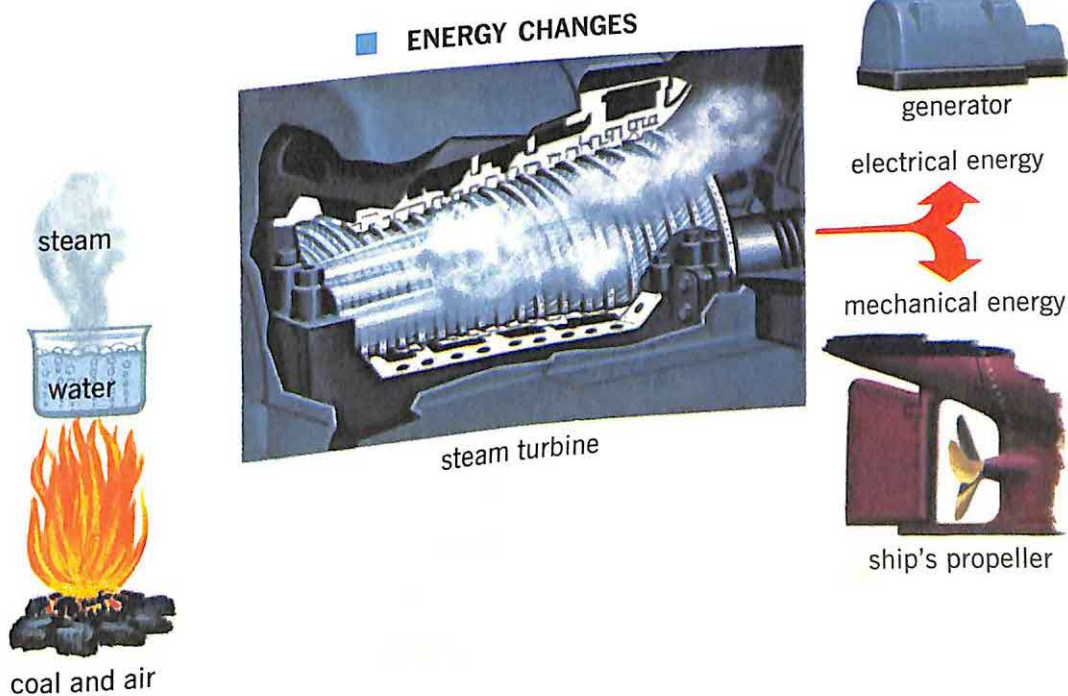
Most of you can lift 50 pounds but with a great deal of effort. With the help of a simple machine you can lift much more. Apply a force of 50 pounds to a block and tackle with four ropes between the pulleys, and what weight can you lift? Each rope supports 50 pounds, making a total lifting force of 200 pounds—enough to lift a small piano! The block and tackle helps you multiply the force of your muscles; but have you done more work? No. Although you have used a machine to multiply the force of your muscles, the force must be applied through a longer distance. The distance is four times as far.

We must put just as much work into a simple machine as we get out of it. Machines may multiply force, but

they do not increase the total amount of work done.

In order to do work, we must have a source of energy. Our energy comes from the food we eat. The energy in food supplies our muscles with the force to push against an object. No matter what kind of work is being done, energy is needed. Using a machine does not eliminate the need for energy. A machine only transfers the energy from one place to another.

In any study of science much time is given over to the study of energy. Energy can be changed from one form to another. Steam from boiling water can turn a turbine. ■ The heat energy changes the water into steam, and the energy in steam becomes mechanical energy in a turbine. Mechanical energy can be transformed into electric energy by a generator and used for many purposes.



We do not gain energy or lose energy when we change it from one form to another. Neither do we gain or lose energy by using a simple machine. We get no more *energy* out of a machine than we put into it. We get no more *work* out of a machine than we put into it.

This is also true of matter. Matter can be changed from one form to another, but matter is neither gained nor lost when it is changed in a chemical reaction.

For example, iron combines with oxygen to form a new compound, iron oxide (rust). Suppose you try to make some iron oxide by exposing a certain amount of pure iron to the oxygen in the air. To make 40 grams of iron oxide, you must use a total of 40 grams

of oxygen and iron. In this chemical reaction, no new matter is made; no matter is destroyed. The matter is only changed in form. This is true of all chemical reactions on earth. Would it be true of chemical reactions taking place elsewhere in the universe?

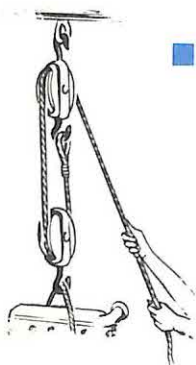
When we multiply a force with a simple or compound machine, no energy is gained—no more work is done; but we are using the force to greater advantage.

Man has learned to use machines to do work. He has learned to use force wisely because he has learned to use it to greater advantage in doing work. The word *work* is used here in the scientific sense. Clearly, science demands that we use our concepts accurately.

Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts of this unit by doing these problems.



1. A man is applying 100 pounds of effort to the pulley machine at the left. ■ The weight he is lifting must be
 - a. 100 pounds
 - b. 200 pounds
2. To raise a barrel to the rear of a car, it would be best to use
 - a. an inclined plane
 - b. a lever
3. To stop accidents on a slippery road, it is best to use sand to
 - a. increase friction
 - b. decrease friction

4. Which of these statements are true? (All may be true. None may be true. Some may be true and some may be false.)

a. A simple machine may multiply force, but it does not increase work done.

b. A simple machine does not produce more work than is put into it.

c. A simple machine does not produce more energy than is put into it.

5. Test your understanding of the main concepts in this unit by using each of these key words in a sentence.

work

pulley

gears

save force

wheel and axle

inclined plane

wedge

force

simple machine

lever

winding inclined plane

multiply force

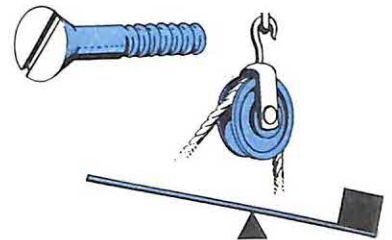
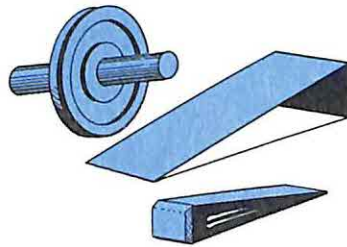
increase work done

compound machine

multiply speed

QUICK TEST

1. Name the simple machines shown in the illustration below: ●



2. Below are four compound machines which are operated by hand. Of which simple machines are they made?

a. juice-can opener

b. scissors

c. meat grinder

d. fork

3. Name one compound machine that contains all of the simple machines listed below.

a. lever

b. wedge

c. wheel and axle

d. screw

FOR YOUR READING

If you are interested in machines and engines, then you might want to read:

1. *Machines That Built America*, by Roger Burlingame, published by Harcourt, Brace & World, New York, 1953.

This is the story of the inventors who built the machines that helped make our nation great.

2. *Machines*, by Robert O'Brien, published by Time, Inc., New York, 1964.

This is an interesting book with some good pictures of the machines that make your life easier.

ON YOUR OWN

There are two additional investigations in this part.

One is on a machine called a perpetual motion machine.

1. A machine that works forever (a perpetual motion machine).

Here is an example of a perpetual motion machine called a perpetual rocker. ■ It looks like a kind of lever, with the fulcrum (the point on which it rests) exactly in the center.

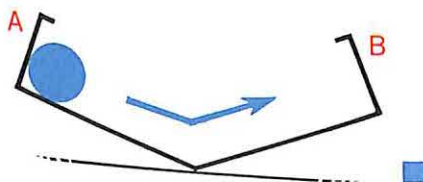
It works like this: the heavy rubber ball is started rolling with a good push (at A). It rolls down the hill and up. As it hits the other end (marked B), it bounces off and starts rolling back. It hits the end again and starts rolling.

The machine rocks back and forth, back and forth, back and forth *perpetually* (forever). What is your hypothesis?

Will it work?

If yes, why?

If not, why not?

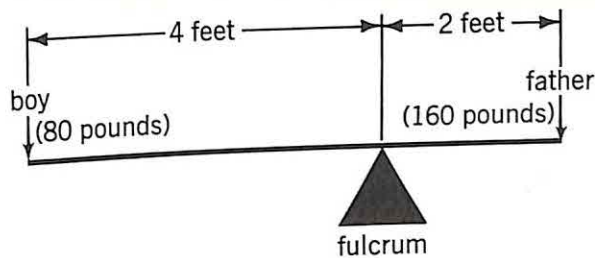


2. Balancing a seesaw.

A boy and his father were walking in a park when they saw a seesaw, which is really a simple machine, a lever. It is a board which is balanced on a fulcrum. (See below.)

In any event, the boy wanted to get on the seesaw and to *balance his weight against his father's*. He persuaded his father, as boys sometimes can, to get on the board with him.

It just happened that the boy weighed 80 pounds, and that his father weighed 160 pounds, twice the boy's weight. Below is shown how they finally balanced themselves. ●

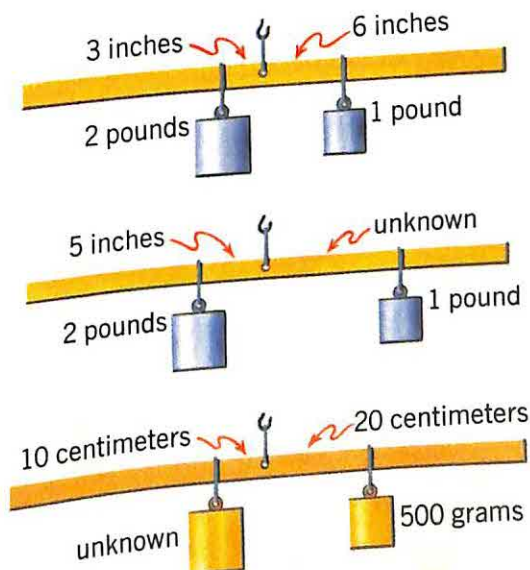


Do you see why they could balance? Try the investigation below.

Take a yardstick and hang it in the middle with a string, as shown below. ▲



Use two weights, one twice the weight of another. Try to balance them on a measuring stick, as shown. ◆ One way of balancing these weights is shown. Try several others to find the concept that explains the balancing of weights.



CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

(Text pages 194–229)

UNIT CONCEPT

The amount of energy gotten out of a machine does not exceed the amount of energy put into it.

A Preview of the Concepts

Unit Five

MOLECULES IN ACTION

The pupils investigate one of man's greatest sources of energy, the energy of moving (vibrating) molecules. They follow man's quest for ways to put this energy to work; that is, to harness the energy to provide a force to move objects through a distance. They begin to appreciate that these great forces generated enable him to do great amounts of work in a short time.

A VIEW OF THE UNIT

The Industrial Revolution is said to have begun in the early eighteenth century, some 250 years ago. Until this time, except for harnessing moving air and flowing water to machines (windmills, water wheels, sailing vessels), man's chief source of a force for doing work was the force of his muscles multiplied by simple and compound machines such as those studied in Unit Four. Wind and water were unreliable. Winds blew too hard or not at all; streams ran dry in droughts; and man had to work hard to raise enough food to give his animals and himself energy. Moreover, muscles got tired; there had to be time to rest. No doubt man wondered and wished: If only we had more energy and a better way of getting and using it.

Finally, James Watt wondered—and he got an idea. Perhaps the steam from boiling water could be used; it certainly did work in bouncing the lid on a kettle. Perhaps this energy in steam could somehow be hitched to a machine. Perhaps the force of the bouncing lid could move a wheel or a lever. So the piston was soon invented. It transferred a force to a machine, not very efficiently of course, but nevertheless more work could be done than by muscles and machines alone. It was a steady source, too, so long as the furnaces for heating water could be fed enough coal.

The first section of this unit develops the concept of kinetic energy and its transfer and conversion to mechanical energy. In spite of many improvements, steam engines can do only a relatively small amount of useful work. A large amount of the kinetic energy in the molecules of a burning fuel has to be expended in the physical change of water into a gas to get the molecules moving fast enough to deliver a large force.

No doubt many people wondered how a fuel could be made to turn machines directly so that the energy used to heat the water could be used instead to turn the machines. But coal was too bulky. So invention had to wait until oil was discovered. The development of internal combustion machines is the subject of Section 2; they eliminated one stage in the transfer of the kinetic energy of molecules in burning fuels.

With the internal combustion engine came a breakthrough in transportation. Horse drawn carriages gave way to faster and faster motor-driven engines. And man started to dream of flying. He knew moving air had energy and exerted a force. He now felt the pressure of air as he sped through it. Perhaps this air pressure could be harnessed to engines—and in time the airplane was invented. But another concept was needed, too. Bernoulli's principle that unequal speeds of a liquid moving over an upper and an under surface causes unequal pressures and hence a force, seemed to offer promise. The airplane wing was invented—and it worked.

Still man was not satisfied. There were too many moving parts in engines. They ate up energy at a rapid rate in overcoming resistance, especially friction. Eliminate friction, he reasoned—eliminate moving parts—and perhaps more of the energy put into the machine could be translated into useful work gotten out of it. Perhaps he could even get away from the earth and explore space beyond the earth's atmosphere. Section 4 shows how man succeeded.

All of these improvements in engines could not have taken place without an understanding of the concepts relating to energy and force. The concept that matter consists of molecules and that molecules can be given greater kinetic energy had to be understood. Basic to all engines were the concepts formulated by Sir Isaac Newton in his *Laws of Motion*. The essential parts of these laws are reviewed.

You may wish to look ahead to page T-108 and examine the chart in the last section of this unit in the Teacher's Edition. It summarizes the historical development of the uses of energy from muscles to jets.

SUPPLEMENTARY AIDS

All films and filmstrips are in full color. Each is rated according to approximate depth and difficulty of concept. Those rated "Intermediate" are about right for the level of the pupil textbook; those rated "Junior High" are fairly advanced. Full names and addresses of distributors and suppliers are on page F-26.

Gravity, Weight, and Weightlessness (11 min.), F.A., 1964. Film defines weight as a measure of the pull of gravity. Newton's experiment concerning free fall is demonstrated. Scientists use this knowledge in order to launch satellites. (Intermediate)

Satellites: Stepping Stones to Space (17½ min.), F.A., 1964. Through an examination of Explorer I, the pupil is shown some of the instruments satellites carry and what those instruments tell us of outer space. (Intermediate)

Films

How Man Travels Through Space (12 min., sound), Cenco, 1964. Rockets, because of speed, are able to overcome gravity and make space travel a possibility for man. Explains Newton's Law—every action has an equal and opposite reaction. (Intermediate)

Explaining Matter: Molecules in Motion (11 min.), E.B.F. Shows that the rate of molecular motion (vibration) determines whether matter exists in a solid, liquid, or gaseous state. Physical change depends on changes of temperature. (Intermediate)

An Introduction to Jet Engines (14 min.), McGraw-Hill. Through the use of animation, the pupils get a vivid, realistic view of the inside of a modern jet engine. Explains clearly the basic principles of process of compression, ignition, and expansion of gases. (Junior High)

First Men Into Space (Solving Space Survival Problems) (16 min.), McGraw-Hill. Shows, with live photography and scale models, the first American orbital space flight, and the problems of man's survival in this hostile environment—decreased air pressure, weightlessness. (Intermediate)

Rockets: Principles and Safety (11 min.), F.A. Introduces the physical principles upon which rockets work and explains why rocket motors can work in outer space. Rockets should not be built and fired by amateurs. (Intermediate)

What Makes an Airplane Fly? (35 frames), Jam Handy, 1960. Develops the fundamental principles of flight; explains construction and operation of an airplane; the meaning of thrust and lift, and how the forces of gravity and drag are overcome. (Intermediate)

How Do Helicopters Fly? (35 frames), Jam Handy, 1960. Explains that the four forces that act upon an airplane act on helicopters—thrust, lift, drag, gravity. Detailed drawings show parts of helicopter and explain how the pilot controls each of above forces. (Intermediate)

How Do Jets Fly? (35 frames), Jam Handy, 1960. Explains basic principles of jet engine—forces of action and reaction; experiments with balloons illustrate principle. Reviews thrust, lift, and speed of jet in relation to propeller plane. (Intermediate)

Rocket Power for Space Travel (35 frames), Jam Handy, 1960. Defines space and explains why airplanes cannot fly in space. Drawings of rocket show application of Newton's Law. Explains how a satellite is put into orbit by multi-stage rockets; how it continues in orbit; effect of gravity; future of space travel. (Intermediate)

Leaving the World (41 frames), S.V.E., 1962. Shows how rockets are developed and explains rocket power, thrust, and speed of release. Shows pictures of man-made satellites recently launched. (Junior High)

Current Events in Space (47 frames), S.V.E., 1962. Explains how Newton's Law applies to space travel; shows step by step launching of satellite and how it is tracked. Covers first successful moon shot. (Junior High)

Hydrogen-Oxygen-Water (47 frames), S.V.E., 1961. Explains actions of molecules in gases; what happens when hydrogen and oxygen are mixed and ignited. Shows the relationship of the temperature of water and the amount of heat. (Junior High)

Space Satellites (35 frames), Jam Handy, 1962. Explains how a satellite is launched and what conditions cause it to orbit; how it is possible to change the orbit of a satellite; how they are now used and what are future uses. (Junior High)

Starred (°) titles are considered especially suitable for their content and reading level. Names and addresses of the publishers are on page F-24.

Science Reading Table

All About Rockets and Space Flight by Harold L. Goodwin, Random House, 1964. Describes present space vehicles and what we can expect of those to be developed in the near future. Information about the electronic and mechanical devices carried by the rockets, the kinds of information they convey to earth, and conjectures with regard to travel to the stars are included. (Advanced)

°*Dr. Posin's Giants* by Daniel Q. Posin, Harper & Row, 1961. Based on "Window to the World" programs of WTTW educational television station. The scientific work and achievements of 26 famous scientists from Archimedes to Einstein are described with interesting narrative. Sketches such as may have been used in television presentation, photographs of many instruments used, and portraits of each scientist are included. Emphasis is on the scientific achievements and the principles discovered. (Advanced)

°*The Energy Story* by Helen Heffernan and George Shaftel, L. W. Singer, 1963. A fictional story introduces the major theme of the book—the ways in which man is developing new fuels and is using the energy of wind, tides, the sun, and nuclear fission. The importance of energy to run the machines of America and the world is stressed. (Average)

Man Alive in Outer Space by Henry B. Lent, Macmillan, 1961. The story of the men behind America's first man in space; an account of what space surgeons have done to enable man to succeed in his conquest of space. How the seven astronauts were selected for Project Mercury is also described. (Advanced)

Man to the Moon by Hanniford Rush, Rand McNally, 1962. Describes space vehicles in considerable detail. Contains much historical knowledge about the moon. The trip, moon colonies, and private life on the moon are described on the basis of scientific knowledge and research going on at the present time. (Average)

Pioneering in Space by Walter B. Hendrickson, Jr., Bobbs-Merrill, 1961. Includes sections on what space travel is like, requirements for astronauts, spaceships and capsules, and space pioneers including pilots of the X-15. Describes how space problems are discovered and solved. Suitable for reference reading by average readers on selected or assigned topics. (Advanced)

° *Realm of Measure* by Isaac Asimov, Houghton Mifflin, 1960. A virtual encyclopedia of measurement. Begins with the most rudimentary kind of measurement based largely on the human body and concludes with information and explanation of Einstein's Theory of Relativity. A useful reference for average readers. (Advanced)

What Is Heat? by Theodore W. Munch, Benefic Press, 1960. A survey of the characteristics and behavior of heat. Clear pictures and diagrams help to describe how we measure heat and temperature, how heat travels, and the energy and motion aspects of heat. Includes a brief section on modern uses of heat. (Easy)

The Wind by Jeanne Bendick, Rand McNally, 1964. Relates myths and superstitions about the wind, but the major portion is devoted to scientific facts. An extra fillip at the end includes a section on wind sounds, wind sayings, and brief statements about many things like "windjammer" and "windfall." (Easy)

▶ INTRODUCING THE UNIT

Display on your desk an alcohol lamp, a glass of water, a pinwheel, a balloon, and a kettle closed with a lid. Ask how we can get energy out of these objects or give energy to them. The pupils should invent ways, and at least some of them should be tried out. For example, we can light the alcohol lamp, put water in the kettle, and turn it to steam that will move the lid. We can blow on the pinwheel or turn it in a jet of steam. We can blow up the balloon and let it go. What kind of energy is being used? If pupils do not mention moving molecules, tell them that lighting the alcohol lamp sets molecules from the burned fuel in motion, that boiling the water sets molecules of water in motion, and that a push or pressure of molecules of air turns the pinwheel or makes the balloon move. Do you think we can use this energy of moving molecules to do work? That is what this unit is about.

Turn to text page 195. Allow pupils to hypothesize in their answer to the question in the fifth paragraph. At the end of the unit they may return and check their hypotheses.

Section 1: A MODERN GENIE

Pupils, in this section, begin to comprehend why man searched for a means of harnessing sources of energy to get a force to do work that was greater than the force muscles and simple machines alone could provide. They extend their understanding of the concepts of energy and work by investigating the kinetic energy of moving molecules. They begin better to appreciate that harnessing of great forces had to await technological advances.

(Text pages 196-204)

SUBCONCEPT

The energy of moving molecules of air and water provide a force that can be harnessed to do work.

Introducing the Concept

Why do you think Aladdin, in the first paragraph, liked to rub his magic lamp? To get at one answer, each pupil may place his textbook on the palm of his hand and raise and lower it rapidly about one foot without supporting his elbow. What soon happens? (Muscles tire.) How much push do you think you can exert? Pupils may check their guesses by pushing down—at home—on bathroom scales or by squeezing the top and bottom of the scales between the fingers of both hands. Few persons can exert a force with hands or arms equal to their weight. Suppose you can exert a force of 75 pounds. By how much could you multiply this force with a six-rope pulley system? (450 pounds.) Could you lift a 500-pound safe with it? (No.) The radius of a wheel and axle is $3\frac{1}{2}$ feet. Could you use the wheel as a machine? (No. You'd have to be able to reach 7 feet, at least.) Simple machines can multiply the force of muscles only so much; the distance the force must move is limited; muscles tire quickly, and speed and, hence, time is lost.

Where can more force be found? Will air and water do work? Are there any technical problems that limit the forces?

Developing the Concept

Making an air machine. Pupils do not question that moving air and rushing water have energy and exert a force. They have felt or seen the effects of both. Could we capture a quantity of air or water and make it do work? Assure the pupils that it can be done, and let them hypothesize. Use the rising liquid in a thermometer when the bulb is heated by the hand, if a clue is necessary to start them thinking. Can we make a model "air jack" and lift a cube of sugar? Volunteers may set up the machine described on text page 196 and demonstrate it. If the demonstration is repeated, it will be more successful if the balloon is removed and cooler air blown in. Then discuss the kinetic energy of moving molecules. How was the kinetic energy of the molecules of air increased? (Heating.) What happened? Did the molecules of air expand or did they move faster so that they pushed harder? (The latter.) What work was done? (The cube of sugar was raised through a distance.) Pupils may need to draw representations of molecules close together in the unheated and contracted balloon, and the same number of molecules farther apart in the heated and expanded balloon.

Steam engines and work. You may wish to demonstrate steam pressure before doing the investigation on text page 199. Set a kettle half full of water on a source of heat. Replace the lid with a round balloon part full of water (about one cup), so that it rests snugly on the kettle rim. The steam pressure accumulates until it is strong enough to push up under the edge of the balloon. The effect will be more dramatic if you partially plug the spout of the kettle. Pupils may time the pulses of steam molecules and note if the number changes when the heat is increased or decreased. Pupils should hypothesize that changing water to steam pro-

Processes emphasized

Investigation (with design of experiment)
Inventing models
Analysis of data
Hypothesizing
Theorizing
Prediction
Library research
Reporting

Heat gives greater kinetic energy to molecules.

Equipment and Materials

See illustration, text page 196.

A change of state increases or decreases the kinetic energy of molecules of matter.

Equipment and Materials

See text page 199; also the Teacher's Manual for Classroom Laboratory 6.

duces a force to do work. How can we show it? Proceed with the investigation on text page 199, being sure that the pupils exercise proper caution as directed. A Pyrex baby bottle may be substituted for a test tube, and kitchen tongs for the ring stand and clamp. Did the device do work?

The investigation asks how steam can be harnessed. Recall that the force of muscles is multiplied only by applying it to a simple machine. What simple machine might be used so that the force operates continuously? (A wheel and axle.) Steam occupies about 1,700 times as much space as the water producing it. This means, in theory, a mechanical advantage of 1,700. Harnessed to a wheel and axle with a mechanical advantage of 10, the combined mechanical advantages would be 17,000 without any losses. What are some advantages of a steam engine over a simple machine? (It delivers greater force, it doesn't get tired, it makes work easier—so long as there is water and a source of heat to increase kinetic energy.)

Some technological problems. Study the illustration of the piston on page 200. It fits tightly inside the cylinder, doesn't it? Why is this necessary? (Steam would escape around it and some of the force would be lost.) What happens if steam cools? (It condenses to water vapor; its molecules have lost some of their kinetic energy.) If two surfaces are close together, what force is likely to resist motion? (Friction.) If this resisting force becomes too great, what happens? (Heat is generated, and the metals expand—their molecules gain greater kinetic energy—friction opposes the force of expanding steam.) Why was Vaseline used on the cork in the investigation on page 199? (To reduce friction and make the cork move easily; if it hadn't moved, the steam might have broken the test tube.) Pupils should now be ready to infer that new metals had to be invented—alloys for example—that would not expand too rapidly, would not cool too fast, and would be strong enough to stand up under great pressure.

To illustrate the turbine, encourage a volunteer group to devise and demonstrate the model turbine described on text page 201. Holding the turbine wheel in the jet of steam illustrates that a larger amount of the force is directed into turning a wheel-and-axle type machine. How does the turbine reduce losses of force? (No frictional resistance of piston, no change in motion as with piston, no leakage of steam around piston, less time for steam to condense.) The piston merely transfers a force; it does not multiply it. What advantage is gained? (Greater distance through which the force operates and hence a gain in speed.) In terms of technological problems that had to be met, why was the turbine invented and put to use later than piston engines? Actually, many modern turbines are run by steam which has been superheated as high as 700° F., which increases the pressure tremendously—to some, 3,200 lbs. per square inch. Heat resistant alloys had to be invented as well as alloys that would not break apart at tremendous speeds.

Extending the Concept

Showing transfer of a force. A model may be devised to show how a friction belt transfers a force from one wheel to another. Tinkertoy elements and rubber bands can be used. Different sizes of wheels will illustrate gain in distance (speed) as effort is transferred manually. The wheel may be equipped with a turbine and moved as described on text page 201.

Hero's model. Interested pupils may make a simplification of Hero's model from a spice can. First make small holes a half-inch from the bottom on each side and near the corners. Place about two tablespoonfuls of water in the can. Close the top and suspend by a thread over Sterno or an alcohol lamp. Observe the action as steam is generated.

A report. Among the first practical applications of Hero's engine were those of Thomas Savery, Thomas Newcomen, and James Watt. Look up their work and report on the problems they had to meet in their inventions. Railroad buffs can investigate and report on the development of the steam locomotive.

Diagraming energy conversions. All energy used to do work is transformed into a force that does the work and another form of energy, often referred to as a loss. Some heat energy is "lost" because it heats the air around a machine or the moving parts. Energy from the sun is used by green plants and stored as coal; coal is burned to change water to steam; the steam pushes a piston and turns a wheel; the wheel is connected to a circular saw by a belt. What are the energy transfers and the "losses" in each step?

Equipment and Materials

- ... Tinkertoy elements
- ... rubber bands
- ... spice can
- ... nail punch
- ... Sterno or alcohol lamp
- ... thread
- ... support

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. b

Using What You Know. Releasing the force that keeps the spring wound changes its potential into kinetic energy. Releasing the water behind the dam by removing or lowering the dam causes the water to flow and gives it kinetic energy.

(Text pages 203-04)

Section 2: AN EXPLOSIVE GENIE

Pupils investigate the change of potential energy to kinetic energy when fuels are burned. This type of chemical change almost instantaneously multiplies greatly the speed at which molecules move, thus creating a force that, harnessed to simple machines, moves objects through a distance at great speed.

(Text pages 205-11)

SUBCONCEPT

Molecules may be given kinetic energy in a chemical change.

Introducing the Concept

Place a cupful of water in a kettle or beaker, place it over a source of heat, and time how long it takes for it to come to a boil. A tablespoonful of rice grains will show the increasing speed at which the masses of mole-

Equipment and Materials

- ... kettle or beaker
- ... rice grains

Processes emphasized

Observation
Analysis of data
Computation
Library research
Model building
Investigation (of equipment in the environment)

Combustion increases kinetic energy.

Equipment and Materials

See text page 207; also the Teacher's Manual for Classroom Laboratory 6.

Internal combustion engines transfer the force of kinetic energy directly to machines.

cules of water move. While waiting for the water to boil, pupils may read the section up to "A Useful Explosion." Then discuss: Why wouldn't you like to own a steam automobile? Some answers: It would take too much time to "get up steam," be too bulky, result in too much loss of force from boiler to engine parts that do the work. Why is a gasoline car better? Record on the chalkboard pupils' responses and hypotheses without comment, and proceed to the exploration of these questions:

Can a chemical change be harnessed to do work? How can the useful work of an engine be increased?

Developing the Concept

When a fuel burns. On the Fourth of July, a fireworks display produces a great amount of kinetic energy, but it does no useful work other than to drive rockets into the air and explode them for our entertainment. Of course, the explosions do work in the scientific sense. Where do explosions do *useful* work? (Autos, gas engines, etc.) In all these engines, a change from one form of energy to another takes place; a fuel burns, and stored energy is changed to energy of motion.

What happens when a fuel burns? Pupils hypothesize before they set up the investigation on text page 207. Since all fuels are hydrocarbons, they contain hydrogen and carbon. What kinds of substances are formed when fuels combine with oxygen? (Two gases, carbon dioxide and steam.) When a solid or liquid changes to a gas, what happens to the molecules? (They move farther apart; that is, their motion, hence their kinetic energy, is increased.) Such questions as these encourage pupils to draw useful inferences. They may have difficulty understanding that steam is produced by the energy of burning. How hot is a flame? Is it hotter than 212° F.? Steam (water vapor) has about 1,700 times the kinetic energy of the water from which it came (see page T-98). Would carbon dioxide have more kinetic energy than the bit of carbon that combined with oxygen to make it? (Yes. The motion of the molecules is greater in a gas than in a solid.)

After pupils have read "Energy from Burning Fuel," it is desirable that they infer, from examining the molecular diagrams of candle wax and gasoline, that the arrangement of carbon and hydrogen molecules makes the difference between the explosive oxidation of gasoline and the relatively lower oxidation of candle wax. Pupils may have the erroneous notion that solid or a liquid combines directly with oxygen in burning. Both, however, must vaporize (evaporate, or change to a gas), and it is the vapor that combines with oxygen. The speed with which a substance vaporizes at low temperature explains the low kindling temperature of gasoline and the necessity for observing caution with sparks or flames near flammable hydrocarbons.

How does a gasoline engine work? Pupils should read "Exploding Gasoline in a Tube" and study the diagram. Be sure they understand that the purpose of the carburetor is to change a drop or two of gasoline into va-

por. This is done by releasing the gasoline through a fine jet into the large space of the carburetor. The mixing of air and gasoline vapor is in just the right proportions. Too much or too little of either will result in incomplete burning or loss of some of the energy of combustion.

How is the energy of exploding gasoline changed into a force to do work—to move a car at high speeds over a distance? What are some advantages of the gasoline engine over the steam engine? (In addition to the reduction of bulk and the portability of the fuel, pupils should realize that the force supplied by the kinetic energy of the molecules [carbon dioxide and water vapor] in exploding fuel is immediately applied to the piston and transferred by it *inside* the engine; in a steam engine the burning fuel must convert water into steam before the force that does work is available.) As the pistons transfer force to wheels, what advantage is gained? (The wheel, a simple machine, increases speed.)

The changes that take place. After pupils have read "Two Kinds of Change and One Goal," review the changes until they are clear. What kind of change takes place when water changes to steam? (Change of state.) When gasoline changes to vapor? (Change of state.) Is this a physical or a chemical change? Where does this change take place in a gasoline engine? (Carburetor.) What kind of change takes place when gasoline vapor burns? (Chemical.) Where in a gasoline engine does this change take place? (Inside the cylinder.) Where does a chemical change take place in the steam engine? (Outside when fuel is burned.) It is important that pupils grasp the essential idea that the chemical change in a steam engine takes place *outside*, with the result that a physical change transfers a force to the piston. In a gasoline engine, the force resulting from the chemical change is applied directly to the piston.

In conclusion, you may wish to review some of the technological problems that had to be met before gasoline engines could be invented, among them devices to control combustion and materials to withstand the continuing shock of explosions and to minimize the friction of rapidly moving parts.

Extending the Concept

Reports and displays. Automotive enthusiasts may investigate and report on early automobiles and their inventors. An interesting display of automotive history can be used for the bulletin board. Car model collectors may be willing to bring models for the science display table with accompanying labels explaining interesting facts about them.

Sparks and gases. Recall cold, dry weather experiences with static electricity sparks crossing a gap between your hands and another surface. A garage or service station man will probably contribute a worn-out spark plug for examination. Pupils measure the gap. How does it compare with the distance traveled by static electricity? Interested pupils should investigate how the spark is generated and delivered to the cylinder of an automobile.

Both physical and chemical changes occur in steam and internal combustion engines.

Gases and safety. Encourage discussion of situations involving sparks and escaping gases. What scientific reason is behind the caution against lighting a match to try to locate a gas leak? Why do some industries prohibit smoking on their premises? Why are "No Smoking" signs displayed at many filling stations?

(Text page 211)

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. a 4. b 5. a

Using What You Know. Fuel is being burned. An oil-burning furnace is one possible answer.

Section 3: BALLOONS AND PLANES—GOING UP

Pupils investigate ways in which molecules of air exert a force that affects the motion of an object. They see that differences in pressure on inner and outer or upper and lower surfaces will cause an object to move in the direction of the lower pressure.

Introducing the Concept

To approach the idea that balloons can rise—or float—in air, you may wish to start with a demonstration of the push of another fluid—water. Float an empty milk carton in a pan of water. Allow pupils to push down to note that water is pushing up. Half fill the carton with water, and note the level at which it now floats. Now fill it to the brim, capping it tightly. Allow pupils to hypothesize whether the carton will float or sink before you place the carton in the water. You have demonstrated Archimedes' principle that an object is buoyed up by a force equal to the weight of the fluid it displaces. Using two aluminum foil containers, float one on top of the water, crumple the other into a ball and note that it sinks. The greater surface of the plate gives it greater volume (volume of air weighs less than the water displaced); it floats. Since the crumpled plate is heavier than the water it displaces, it sinks.

Now crumple a sheet of paper into a ball and drop it with another uncrumpled sheet. Which hits the floor first? Of course both are pulled to the floor by gravitation, but the greater surface of the sheet of paper holds it up longer. Air apparently pushes up, too. If we fill a balloon with air and another with a gas lighter than air, what would happen? The one lighter than air would rise, of course. Pupils read the section preparatory to the investigation on text page 213. They may wonder what makes atmosphere "thin" high above the earth. About half the earth's atmosphere lies below 18,000 feet. When a balloon reaches the height where the downward pressure of the air in the balloon equals the upward pressure of air outside the balloon, it stops rising.

How does a machine heavier than air fly?

(Text pages 212-17)

SUBCONCEPT

Differences in pressure result in a force acting in the direction of the lower pressure.

Processes emphasized

Investigation
Analysis of observations
Measurement
Computation
Library research
Invention (models)
Reporting

Equipment and Materials

... pan of water
... milk carton
... 2 aluminum foil containers

Developing the Concept

Air across surfaces. To develop the concept that air pressure can be used to do work, you may wish to begin with the investigation. To demonstrate that apples have no special quality of attraction, repeat with other objects, such as Ping-pong balls, or place two cardboard rolls an inch or so apart at the edge of a desk. Blow between them through a straw held parallel to the desk. Encourage observation and curiosity before clarification by discussion.

How an airplane lifts. The concept of lift is not usually developed by one experience. By blowing across the top of a sheet of paper, as illustrated on page 216, pupils see that air is moving faster over the top surface than the lower, but they may not see why the pressure should be less on the upper surface. Encourage them to think of two forces at work. One is the force of gravitation that pulls downward; the other is acting at right angles to the pull of gravitation. Gravitation pulls air downward, giving it pressure; when air moves sideways, it travels over a long distance while being pulled downward. Once an airplane has been lifted into the air, principles of action and reaction are at work. In fact, one school of thought places the major share of lift and flight upon action and reaction, indicating that wings play a minor function in flight (see Section 4).

The trick in designing airplanes was to have air moving across the upper part of the wing faster than across the under part. The diagram of the airplane wing on page 214 shows how this is accomplished. The air must travel farther; it therefore must go faster in the same time. The amount of air is the same, so there must be the same number of molecules spread farther apart. The pressure per unit of surface must be less above than below.

One class laid out a cross section of an air foil with clothesline on the classroom floor. An equal number of pupils moved around each surface. Those moving around the curved surface had to move faster and space themselves farther apart to reach the end of the air foil at the same time.

Some simple arithmetic may be useful. An air foil with a visible curvature, such as a private plane wing, has an average of 23 pounds more pressure per square foot on the under than on the upper surface. Pupils who are model plane enthusiasts have easy access to wing dimensions on standard makes of planes. Calculate the total lift by multiplying the square footage of wing spread by 23. The total will be surprising. This is roughly two thirds of the total lift. The other third is supplied by the angle of the wing to the forward motion of the plane. A propeller-driven transport plane may have 18,000 square feet of wing spread. At cruising speed, this plane can lift itself, its crew, and a cargo of 20 tons.

Technological problems. In addition to understanding the concepts, air engineers had to design engines to develop sufficient speed, so that air moved rapidly enough across the wing surfaces to develop lift. Plane designs had to be tested to decrease air friction, or drag. Steering mechanisms had to be developed. Weight had to be reduced by lightweight,

A difference in pressure may result in motion.

Air moving faster over the upper surface of an object develops a lifting force.

Equipment and Materials

... Ping-pong balls
... cardboard rolls

(See text page 213; also the Teacher's Manual for Classroom Laboratory 6.)

but strong, alloys; for every pound of weight increased the amount of lift needed. Encourage discussion of these technological problems as one more illustration of the teamwork of scientists and inventors.

Extending the Concept

Model plane exhibit. Pupils who are plane enthusiasts may wish to bring models for the science display table. Brief labels and explanations should be attached to each.

Reports. Interesting reports can be made by looking up pioneers of flight and relating the problems they met and overcame. Some of the names are suggested in the investigation on text page 215.

Model wind tunnel. How to build and demonstrate a classroom wind tunnel is described on pages 457-58 of *The Sourcebook for Elementary Science*.

(Text pages 216-17)

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b

(Text pages 218-24)

SUBCONCEPT

An increase in kinetic energy can produce an unbalanced force.

Processes emphasized

Investigation (with model-making)

Observation

Analysis of observations

Hypothesizing

Theorizing

Invention (models)

Reporting (with exhibits)

Equipment and Materials

... tennis ball

... pan

... block of wood

Section 4: JETS AND ROCKETS

The pupils begin to appreciate the increase in amounts of energy that can do work as the number of energy transformations used to overcome resistances are reduced. When energy is directly applied to do work, the force available is multiplied.

Introducing the Concept

Since the forward motion of jets and rockets depends on understanding Newton's Laws of Motion, it will probably be necessary to review these laws, which were developed in detail in *Concepts in Science 5*. The essential parts of Newton's Laws for understanding this section are usually known as the Law of Inertia and the Law of Action and Reaction.

The Law of Inertia states that an object at rest tends to remain at rest and an object in motion tends to remain in motion in a straight line, unless acted upon by an unbalanced force. The Law of Action and Reaction is stated on text page 218.

Roll a tennis ball toward a wall. A push is needed to start it. A push (by the wall) is needed to stop it, although friction will cause the ball to come to rest if the room is long enough. Each push is an unbalanced force. Another example: Push down on a block of wood floating in a pan of water. You can feel the water pushing up on the block of wood. It pushes up just as hard as you push down. Push harder. Your push is the unbalanced force so the block goes deeper into the water. When you remove your hand, the block bobs up to the position in which the downward push just balances the upward push. Inertia takes over when the forces

are in balance. Kick a tin can. You unbalance the forces that hold the can at rest, and off it goes, but it soon comes to rest.

On earth, gravitation and friction tend to bring objects to rest. Gravitation keeps them from flying off into space; friction keeps them from sliding around. In space, things are different. For example, the Gemini capsule tended to keep on going; its sideways force was just enough to balance gravitation. And there is little or no friction in space.

This brings up a nice question: How can you move about without friction—without something to push against? How were Astronauts Edward White and James McDivitt able to get back to earth? How have the other astronauts managed it? The answer lies in the Law of Action and Reaction. Understanding of this law led technologists to invent ways to make an action produce a reaction directly, to put energy in and get work out with as little loss to resistance as possible.

How do jets and rockets work? How do they develop a force that gives them speed and ability to change direction?

Developing the Concept

Action and reaction. Strangely enough, Hero of Alexandria (see text pages 202–03) invented an action-reaction engine without knowing the principle. The action of the escaping steam caused a reaction (rotary motion). Does this remind you of a lawn sprinkler? The action of the escaping water causes a reaction (motion of the arms). All the force (pressure) of the escaping water is inside the arms; it is translated into motion. Note that we have been careful not to say that the escaping water pushed against the air. (Remember that Astronaut White maneuvered in space with a small jet gun held in his hand; you can't push against matterless space.)

Let's try another example. Balance a bowling ball as if you were going to throw it instead of roll it. It pushes against your hand. You put the force of your shoulders and arms into throwing it. You push against the ball; the ball pushes against you. Action-reaction; but you unbalanced the forces; you pushed harder (that is, you added some force) against the ball than the ball pushed against you. The ball moved away—though perhaps not very far! If you had been on roller skates you would have moved back. Astronaut White had to be very careful not to push too hard against the Gemini capsule. Action-reaction again! Both forces were nicely balanced; White and the capsule were traveling at the same speed in space with no resistances. The capsule and White would have pushed each other away, because the push of White and the capsule against each other would have produced an action in one and a reaction in the other. Both capsule and astronaut would move.

Let us see how far we have come in our study of the use of moving molecules. In Unit Four we studied simple machines that multiplied the energy of the body. In Unit Five, we have been studying engines that multiply forces supplied by the energy of moving molecules. In Section 1,

Every action has an equal and opposite reaction.

the force originated *outside* the machine and was translated into a physical change that created a force (steam pressure). In Section 2, molecules were given kinetic energy *inside* the machine and the force applied directly to moving parts (simple machines). In Section 3, we studied pressure of air molecules *outside* the object being moved; actually making unbalanced forces do work. In this section, we study how to build up the pressure of moving molecules *inside* an object to be moved. Release of this pressure (action) applies a force directly (reaction) that moves the object in the opposite direction. The force of moving molecules is transferred, with little loss, directly into a force that does work.

Jet engines. Blow up a long balloon. You have packed molecules of air into it under pressure. What will happen when the pressure is released? The answer is of course obvious, but you can't pack much pressure into this type of device. Is there any way to keep pumping pressure into a device so that molecules blasting out one end will produce a steady reaction and thus steady forward motion? Can you invent a device using a turbine, air pressure, and fuel? After the pupils hypothesize and invent, let them read "A Jet Plane Takes Off" (text pages 218-20). The compression of air builds up sufficient heat to ignite the vaporized kerosene, which expands just as all liquids do when they change to a gas. This builds up tremendous pressure that is released through the tail pipe, turns the turbine that is connected to the compressor, and keeps up steady delivery of a force (supplied by the kinetic energy of moving molecules). Jet engines are useful for horizontal travel within the earth's atmosphere, but at a height where air resistance is low because there are many fewer molecules to provide frictional resistance. Heat and pressure were technological problems that had to be met by the invention of new metals.

Rocket flight. Rockets are designed to escape the pull of gravitation. Since they travel where there is no air, how can fuel be burned? Will they need turbines? After pupils have made guesses (they should be fairly educated ones by this time), let them read "A Rocket Blasts Off" and discuss the problems of landing on the moon and returning from it. The technological problem of overcoming the heat barrier on re-entry into the earth's atmosphere had to be met by the invention of heat-resistant materials. See reference to cermets on page T-34.

Changing speed and direction. You are in space. You cannot use rudders or wing flaps because there is no air. How can you steer a capsule? How can you slow it down for a soft landing on the moon? How can you land safely on return to the earth? Pupils who have read of the exploits of space travelers will have a wealth of information. Be sure that their information about hand rockets, retrorockets, positional rockets, etc., is related to the laws of action and reaction, and to the operation of unbalanced forces in altering inertial motion. For example, if you wished to slow down a capsule, in which direction would you fire the rockets? If you wished to move to the left, in which direction would you point the rocket? (The action and reaction must be opposite each other.)

Action and reaction, resulting from kinetic energy given to molecules, can produce an unbalanced force.

Equipment and Materials
... balloon (sausage type)

Rockets and jets operate on the same principle, but rockets convert kinetic energy directly into force.

Action-reaction can be used to change speed or direction of motion.

Extending the Concept

Demonstrating the effect of compression on a fuel. If school regulations permit, either in the building or on the grounds, pour a teaspoonful of kerosene into a small metal container such as a bottle cap. Try to light it with a match. The match goes out because a match flame will not raise the temperature of the kerosene enough to vaporize it. Light a candle and pour the kerosene into an atomizer and squeeze the bulb toward the candle flame. At every squeeze little flames leap up above the candle. Why? (Kerosene must be broken into small particles to permit oxygen to combine readily with it.) Wicks in kerosene lamps serve the same purpose.

Building models. The diagrams of rockets and jets in this section may be reproduced with card or tagboard in two dimensional cutouts, and the action demonstrated. By cutting a mailing tube in half, a pupil clever with his hands may design a three-dimensional cutaway model with Tinkertoy parts and cutout pinwheels.

Bulletin display. Jet and rocket enthusiasts may contribute models they have put together from commercial kits; others may collect pictures and news releases on planes, jets, and rocket travel for placement on the bulletin board.

Equipment and Materials

... kerosene
... teaspoon
... bottle cap
... atomizer

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. a 5. a

Using What You Know. 1. It is not possible. Jets require compression of a large volume of air into a small space, and there is no air on the moon.
2. The squid would go in the direction opposite to the jet of water. It would go forward if it squirted the jet behind it.

(Text page 224)

Section 5: THE MAIN CONCEPT: THE USE OF MOVING MOLECULES

The pupils review kinetic energy of moving molecules and see how science and technology have developed ways of directing more and more of the force generated into useful work. Some force must always be used to overcome resistances; hence, the energy put in is greater than the useful work got out. The total work is never more than the energy put in.

CONCEPT SUMMARY

A Saturn rocket stands on its launching pad. The countdown has begun—5, 4, 3, 2, 1, *Lift*. A roaring jet of searing gases blasts from the base of the rocket; the rocket slowly rises, rapidly picks up speed, and in a few minutes is traveling nearly 18,000 miles per hour. Does the rocket have energy on its launching pad? (Yes. The fuels in each stage of the rocket have potential energy—stored chemical energy.) Every object in motion has kinetic energy. What provides the kinetic energy that moves the

(Text pages 224–29)

CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

UNIT CONCEPT

The amount of energy gotten out of a machine does not exceed the amount of energy put into it.

How do potential energy and kinetic energy differ?

How are fuels a good source of kinetic energy?

Equipment and Materials

- ... mailing tube
- ... pinwheel

How is pressure used?

Why is space flight so recent?

How has man learned to use energy?

rocket? (The burning of fuels sets molecules in rapid motion; they have kinetic energy.)

What happens to the molecules when a solid or a liquid changes into a gas? (They take up more space.) How do they move? (In all directions.) How can they be made to move in one direction? Who can invent a way with this mailing tube and a pinwheel? (Blow first against the pinwheel; then blow through the tube with the pinwheel at the same time distance from the end as it was from the mouth. It should move more rapidly.) What does this model resemble? (A jet.)

Review the principle of flight. Does an airplane wing create an unbalanced force? (Yes. As it cuts through the air, the operation of Bernoulli's principle unbalances the pressures on the wing surfaces.) Actually, an airplane wing is a special kind of machine. In a jet, the kinetic energy of the molecules is increased by heat and pressure (compression by the turbine), which multiply the force. Releasing the pressure in a jet chamber increases the action (force) and thus the reaction. Greater speed results from the greater force.

As you raise this question, you may wish to drop a hint by also asking: What concepts had to be developed and what inventions had to be made? Why were they so difficult? The chart that follows will give clues.

Once man learned that kinetic energy could provide a force to do work, he searched for ways to convert it to greater and greater forces and to bring these forces under control. It would be useful for the pupils, while they read this section, to outline the historical sequence of this development. Perhaps you will wish to place on the chalkboard the headings in the following table and start the table for the pupils:

Stored energy source	Transferred as force by	How work is done
Food	→ muscles of man	→ Directly by muscles
Food	→ muscles of animals	→ Directly by muscles
Food	→ muscles	→ simple machines → Multiplying effort force
Food	→ muscles	→ compound machines → Multiplying force further
Fuels	→ steam → piston → machines	→ Kinetic energy of fuels converted into kinetic energy of steam; force transferred by piston and multiplied by machines
Fuels	→ piston → machines	→ Kinetic energy transferred as force by piston and multiplied by machines
Fuels	→ machines	→ Force multiplied directly by machines
Fuels	→	→ Kinetic energy of molecules does work directly by action-reaction

With many classes, you may wish to place the full chart on the board, leaving off the last column and developing by questioning. Incidentally, do not overlook the fact that action and reaction is at work in all instances, since every action (force) is opposed by a reaction (another force). The piston is merely an action-reaction device that transfers an unbalanced force; that is, a force that overcomes the tendency of a body at rest to remain at rest or in motion to remain in motion in a straight line. Kinds of machines and engines should be cited as examples, and the energy conversions traced. Pupils should note the limitations of food as a source of energy and of muscles as a mechanical means of applying the force generated. Fuels have tremendous energy. Each step in the development in using the kinetic energy of moving molecules was concerned with eliminating resistances so that the full force developed by kinetic energy could be applied directly to do work.

A display of the history of man's inventions for using energy would make a good culminating activity for this unit.

(Text pages 226-29)

FIXING THE MAIN CONCEPTS

Testing Yourself. 1. The heating of tires in summer causes molecules of air to move faster and exert pressure which may be greater than that recommended for safety. The reverse is true in winter. 2. In a steam turbine, the kinetic energy of fuel is used to change water into steam; the kinetic energy of steam turns the turbine. In a jet, the kinetic energy of the burning fuel turns the turbine directly; more of the energy of the fuel is used to do useful work. Also, the steam will undergo a physical change as it cools and the molecules will move closer together. 3. The water sets the air in motion. The air inside the shower is moving faster than the air in the room; hence, less pressure (Bernoulli's Principle). 4. The ball was pushing against Joan; Joan was pushing against the ball. The motion of each is an illustration of action-reaction. 5. Jets and autos burn fuels inside the engine and are therefore internal combustion engines. 6. The rolling logs and the high fly illustrate kinetic energy. 7. Consult the glossary, text page 422.

On Your Own. A. 1. 18,000 miles per hour ($5 \times 60 \times 60$.) 2. 25,200 miles per hour ($7 \times 60 \times 60$.) B. $\text{Work} = \text{Force} \times \text{Distance}$.



UNIT FIVE

MOLECULES IN ACTION

On a hot summer day the concrete pavement may expand and buckle, creating a serious bump in the road.

On a cold winter day water may freeze and expand, causing a pipe to burst and creating a serious water problem.

In late summer, storm warnings are up and small craft take to the safety of a harbor. A hurricane rages unchecked, leaving a path of destruction in its wake.

You cannot see the action which caused the highway to buckle or the pipe to burst, nor can you see the wind that caused so much damage. You can only see the effect of the force and the *action*. In each case, the effect came from the motion of molecules. You cannot see them; but moving molecules can exert tremendous force.

For example, moving molecules in an engine can send a train speeding along its track, or an automobile speeding along a freeway, or a missile soaring through the air. Can you explain how the motion of invisible particles can do so much work?

Perhaps you would like to know how anything too small to be seen can do work. This unit will help you. It explains how man, as scientist and engineer, uses his brain and hands, imagination and skill, to change his environment with the force of moving molecules.

1. A Modern Genie

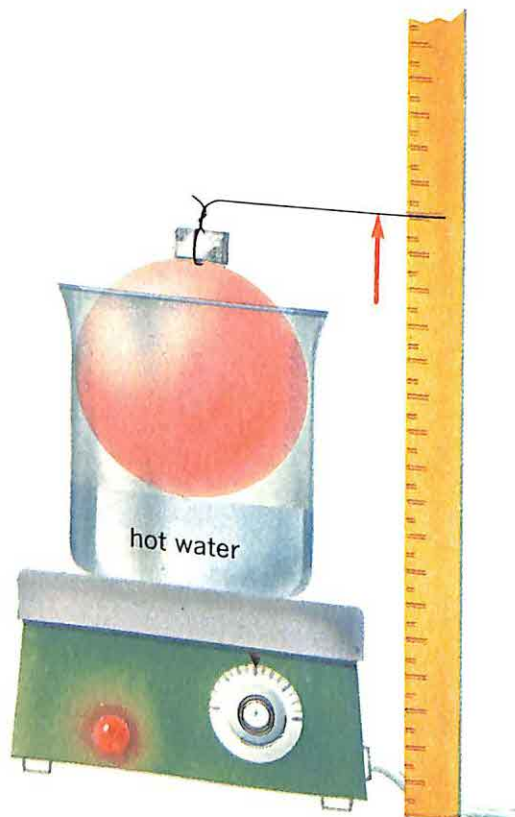
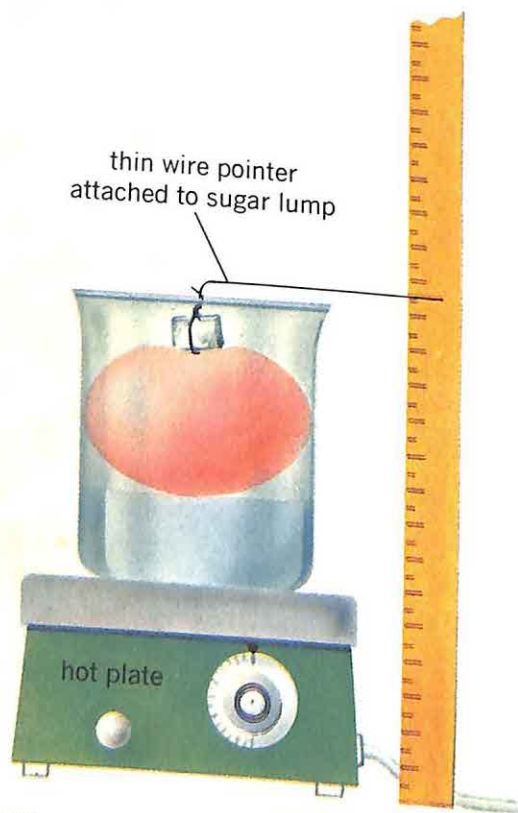
Do you remember the story of Aladdin and his magic lamp? When Aladdin rubbed the lamp, the genie came forth to do Aladdin's bidding. He had tremendous energy; he could do anything Aladdin demanded, no matter how difficult.

Of course, this is only a story, and we do not really believe such things can happen; but man has learned to control a "genie" or two that will rival Aladdin's. Suppose we try to imprison a genie of our own. Let us begin with a small genie; we can imprison a larger one later.

Suppose we bottle up a "modern genie" in a balloon machine like the



one shown in the picture. ■ What can this machine do? What makes it work? It is made of several common items: a balloon, a hot plate, a Pyrex beaker, and some water. What happens to the balloon when the water in the beaker is heated? What makes it happen? What happens to the cube of sugar? Perhaps the ruler will give you a clue.





Before you go on, take a deep breath. Breathe out. You cannot see the air you breathe in or the air you breathe out; yet you know that you have breathed in some air.

What is air made of? One explanation is that air is made up of particles, particles too small to be seen. The small particles of air are molecules. Molecules of the gases that make up air are too small to be seen, even with the help of a powerful microscope; yet there is evidence that molecules do make up the matter which surrounds us. Do you know of any such evidence? What do you know already about the nature and behavior of air?

You may recall making these two discoveries about air in earlier science classes:

Air is invisible.

Air takes up space and has mass.

The evidence indicates that air is made up of particles (molecules) of matter which are too small to be seen, and which are constantly moving. What can moving molecules do?

Molecules of air can be our modern genie. They have energy, which means they are able to do work. *Energy is the ability to do work.*

How can the molecules of air inside a balloon do work?

Take a balloon and blow it up. The molecules you cannot see have expanded the rubber balloon. Now take the balloon and use it to make the machine shown in the picture. This may not look like a machine, but it is. It will do work; the molecules of air will do the work. (Refer to the scientist's definition of work on page 184.) The energy of moving molecules in this machine will lift a cube of sugar; it may even lift several cubes of sugar.

This is a very small "genie," and it does very little work; but you will discover later how moving molecules can lift a plane high into the air or send a rocket to the moon.

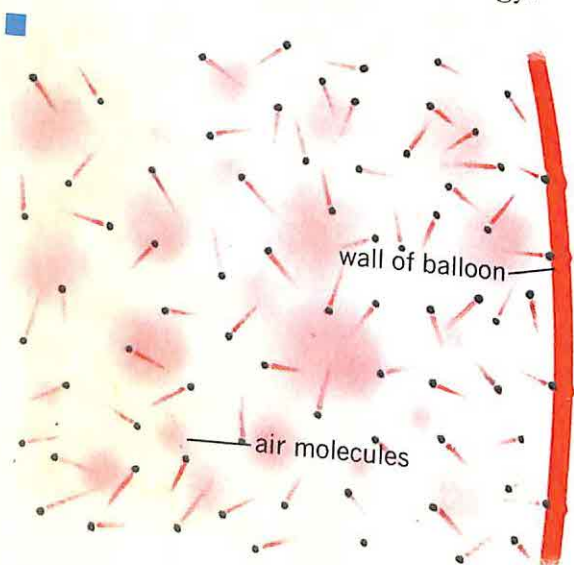
The balloon "machine" does work as the walls of the balloon stretch and lift the cube of sugar. The balloon stretches as the volume of air inside expands. The air expands because the molecules are moving faster; they have gained kinetic energy. As we found earlier, kinetic energy is the energy of motion. A bowling ball rolling toward the pins has kinetic energy. ● A moving locomotive has kinetic energy. Water turning the generators in

a huge dam has kinetic energy. Molecules in the air have kinetic energy; they are always in motion.

Heat increases the kinetic energy of the molecules, so that they move farther apart. In that way, the molecules tend to occupy more space. Whenever the molecules of a gas are heated, the motion of the molecules is increased; the gas expands.

As the kinetic energy of a gas increases, its *force* against the walls of the container increases. In your small "genie" the molecules of air push against the inside of the balloon and expand the balloon. Recall the scientist's concept of work: *Work is done whenever an object is moved through a distance or whenever a force acts through a distance.* The piece of sugar is moved as the balloon expands. The expanding air stretches the sides of the balloon and lifts the cube of sugar. ■

The molecules of air could do work because they have kinetic energy.



This is an important concept: When matter (solid, liquid, or gas) expands, it can exert a force on anything nearby. A force is a push or pull that can change motion. Expanding matter can do work because of the force exerted by its moving molecules. If we can harness the energy of moving molecules, that energy can be transferred to do useful work. That is, *force* is used to move an object. *Work is done as the force moves the object through a distance.*

Let us put some energy to work. The energy comes from matter in motion. By the word "matter," we really mean the molecules, or invisible particles, of which visible matter is made. How can we do it? Simple! We must get the matter to expand, as it will do in the investigation on the opposite page. Try it.

An Explanation: Moving Molecules

As heat is applied to water, the molecules of water move faster and farther apart. As they move faster, many of them escape into the air at the top of the tube. Because kinetic energy increases at a higher temperature, the molecules of both water and air push harder when they hit the cork at the top of the tube.

The water in the Pyrex tube, which you used in your investigation, expanded as it became steam. The force of the moving molecules (of both the steam and air) pushed against the cork. The cork flew out as the gases suddenly expanded. Work was done

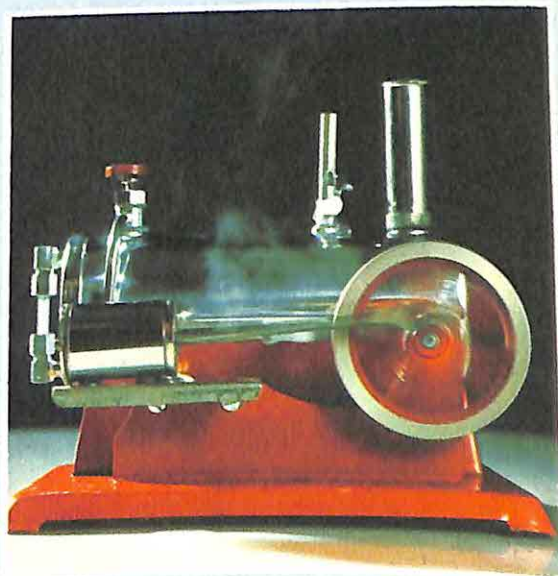
AN INVESTIGATION into How an Expanding Liquid Can Do Work

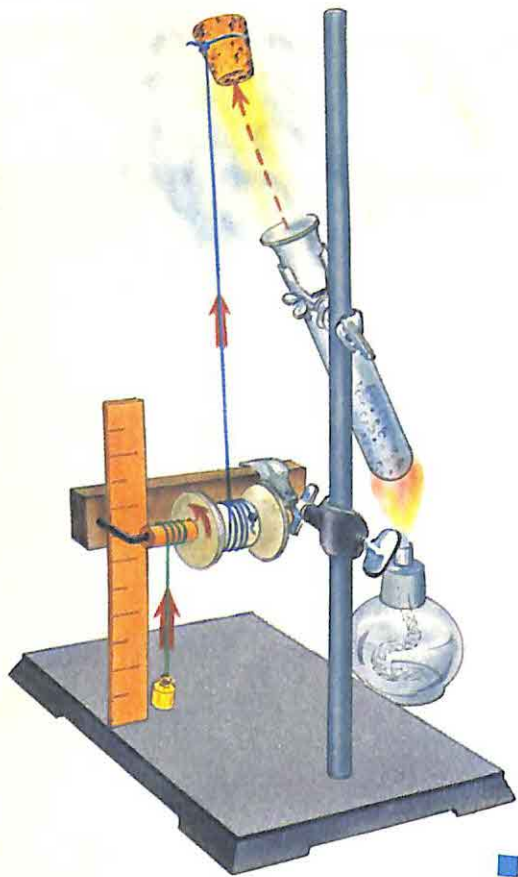
Needed: a Pyrex test tube; a cork stopper to fit; Vaseline; an alcohol lamp or Bunsen burner; a toy steam engine

Fix a Pyrex tube in a clamp, as you see in the picture. Be sure to use a clamp that can be tightened, one that screws together. Pour about an inch of water into the tube. Rub a little Vaseline onto the stopper and fit it into the Pyrex tube. (*Be careful not to point the stopper toward anyone.*) Heat the tube gently, moving it back and forth over the flame. Watch to see what happens. Suddenly, the stopper flies out of the tube. ■ Why?

Now examine the toy steam engine. As you do so, compare it with the diagram of a toy engine on the next page. To operate the engine, heat the water in the boiler. Soon the wheel begins to turn; it turns faster and faster. ● How is the energy of the expanding water being used? Could this kind of energy be used to do work in a large machine—for example, in a factory or on a ship? How?

Additional Investigation: Can you find a way to make the toy steam engine do some *useful* work? If you have an Erector set, or if you are good at building things, try to construct a machine that can use your engine for some useful purpose.





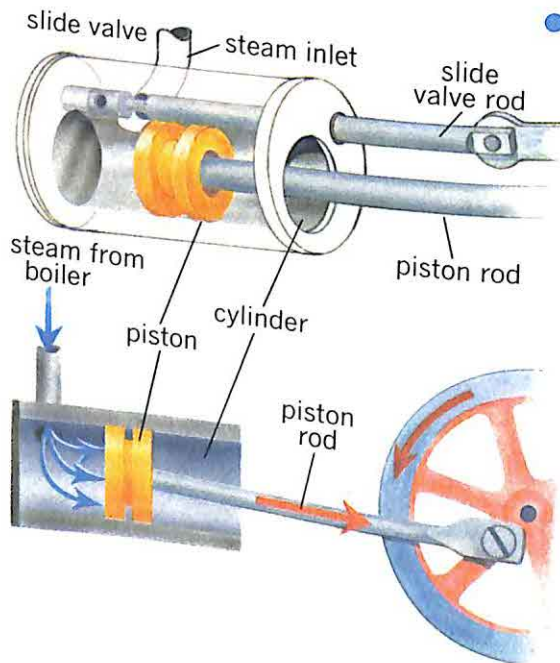
by the moving molecules. The work was not very useful, was it? If you had been able to tie the cork to a shaft and to a wheel, the molecules of the gases might have done useful work as they expanded. ■ The wheel would have turned and lifted the weight for you.

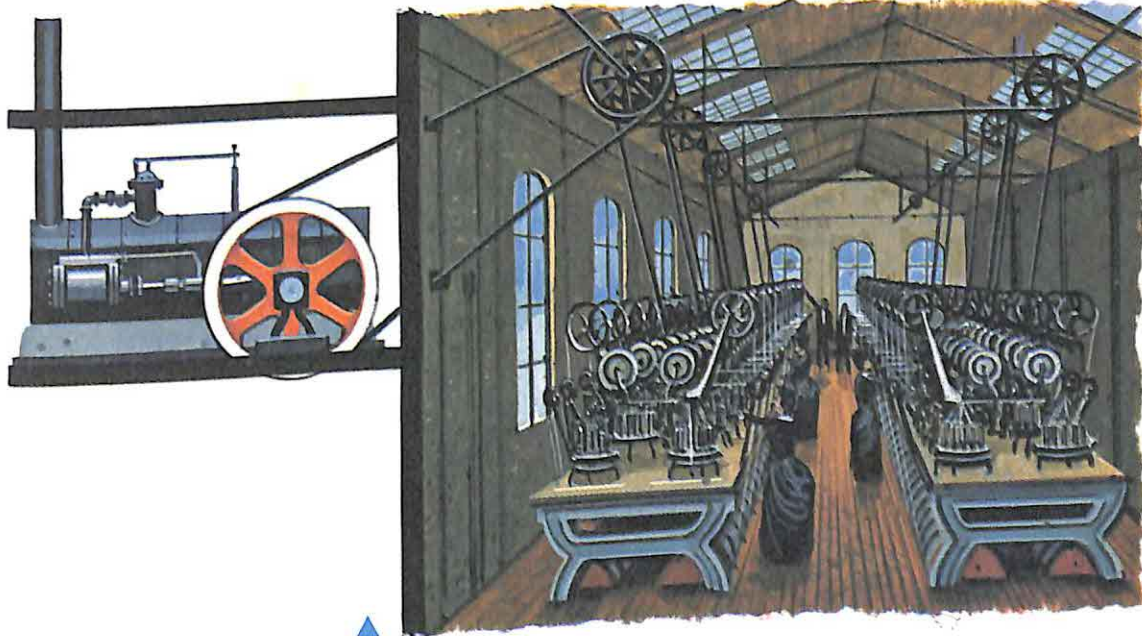
Blowing the cork from a test tube is used as a model of the idea behind the work of a steam engine. In the model steam engine, water is boiled. It is changed from liquid to steam (which is a gas). The force of the steam does useful work by pushing the piston. The illustration shows the piston of a toy steam engine. ● It is

round, something like the cork, and can slide back and forth. The force of the piston, sliding back and forth, is used to turn the wheel. ● The energy of expanding steam is thereby transferred to the turning wheel.

How can a piston-operated steam engine do useful work? In a factory, the piston turns a wheel which, in turn, can turn other wheels of other machines. A century ago the piston steam engine, as shown in the picture, was used to run the machinery in many factories. ▲

The wheel attached to the steam engine had a flat belt around it. The belt turned a shaft which transferred the energy from the steam engine to other wheels of other machines throughout the factory. ▲ These machines did the work of many men, all because the force of expanding steam can be transferred to turn a wheel. In





a steam locomotive there are two or four pistons. Each one turns a wheel.

The piston steam engine was at one time the most important kind of engine we had. It was used in factories, mines, ships, locomotives, and pumping stations; but it is not often used any more. It has been replaced by more modern engines. Read on to find out about a more modern type of steam engine.

Instead of a Piston

You have seen pinwheels and windmills. The energy of moving air (wind) turns them. Windmills can do useful work such as pumping water or grinding grain into flour. Moving steam can also turn a special kind of wheel. This special kind of wheel is called a **turbine** (tûr'bin).

Make a small turbine out of aluminum foil, shaped like the one in the

picture. ♦ If you have no aluminum foil, shape your turbine from heavy paper cut from a milk carton. Place about 1 inch of water in a Pyrex test tube and plug the opening with a one-holed stopper or modeling clay with a hole through it, as shown. ♦ Heat cautiously over a flame and direct the jet of steam against the turbine. Note how it turns. This arrangement concentrates the fast-moving jet of steam against the pinwheel turbine, so that it turns. ♦



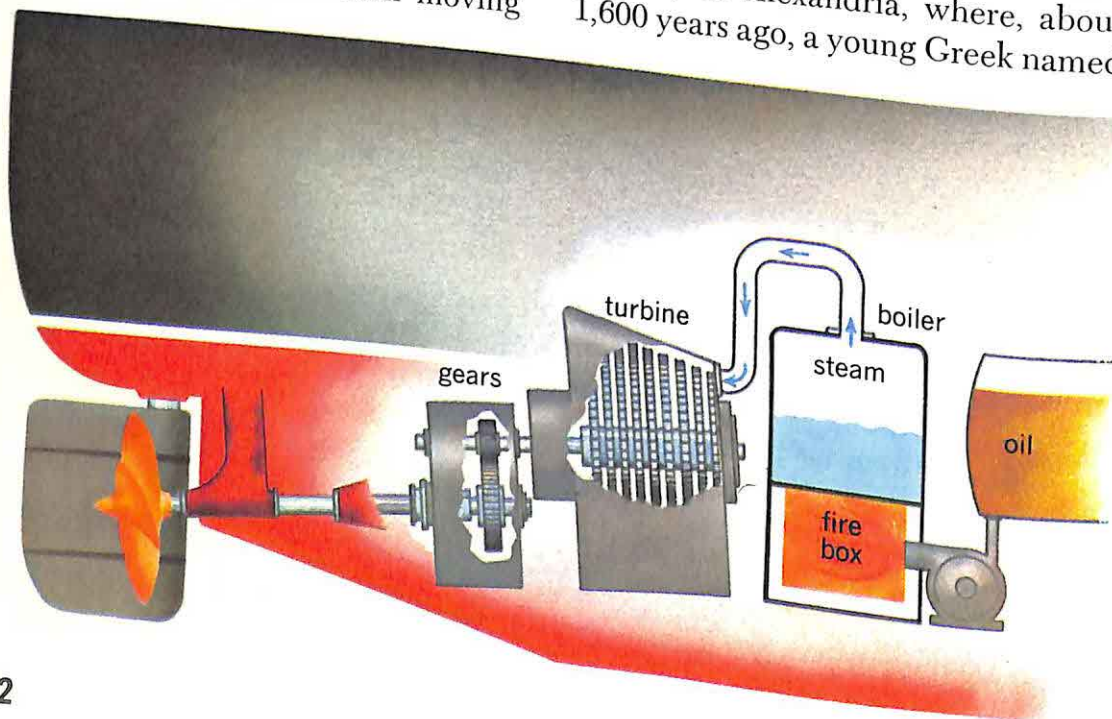
In a modern steamship, the steam from a boiler turns a turbine, a bigger one, of course. The steam is directed against the blades of the turbine; the turbine turns a shaft, which is connected to the propeller. The shaft turns the propeller, and the propeller pushes the ship through the water. Study the diagram which shows how a turbine turns a ship's propeller. ■ The energy of burning fuel, such as coal or oil, heats water in a boiler. The water makes steam. The expanding steam turns a turbine instead of pushing a piston. Steam turbines are better for many purposes than are piston engines. They do not wear out as fast because there are fewer moving parts; friction is less.

Also, because they have fewer moving parts, steam turbines do not waste as much energy as a piston engine. Some of the energy of the fuel must be used to work each moving

part of an engine. Since the turbine and shaft are turned by the steam directly, much more of the fuel's energy is used to push the ship. Machines that convert the greatest amount of the fuel's energy to do useful work are said to be the most efficient.

Steam turbines are used to run many of the largest ocean liners, and they also are often used in running electric power plants. The turbines turn huge generators, which provide electricity to light our homes. Turbines can be turned by other things as well as by steam; they can be turned by moving water, by the explosive power of gasoline, or by moving air. Do you think that particles of sand sliding down a chute could turn a turbine?

The steam engine is nothing really new. On a map of Egypt, you will find the city of Alexandria, where, about 1,600 years ago, a young Greek named



Hero made a steam engine that worked! Look at the picture of Hero's engine. ● What made it spin around?

Hero's engine worked because the heat energy from burning wood makes the molecules of water move faster; the kinetic energy of the molecules is increased. As the kinetic energy of the molecules of water increases, the water begins to boil. Then the water molecules escape from the surface to become steam. When water expands to form steam, the molecules of water can exert enough force to do a great deal of work.

How did the steam make Hero's engine move? **Clue:** Why does a jet plane move? Why does a rocket move?



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. If the movement of molecules could be stopped, the molecules would no longer have
 - a. kinetic energy
 - b. weight
2. One way of increasing the energy of molecules is to
 - a. apply heat to them
 - b. remove heat from them
3. When a closed balloon is made to expand, the number of molecules of air in the balloon
 - a. increases
 - b. remains the same
4. As a closed balloon expands, the molecules of air in it
 - a. increase in size
 - b. move farther apart

B. Write a paragraph or two on this topic: One Way of Putting Molecules to Work.

**USING WHAT
YOU KNOW**

A. A stone lying on top of a hill has stored energy, or **potential energy**, as it is called. An electric battery has potential energy; so does the wound spring in a toy car or a tankful of gasoline. When an object has potential energy, it means that it has the capacity to do work.

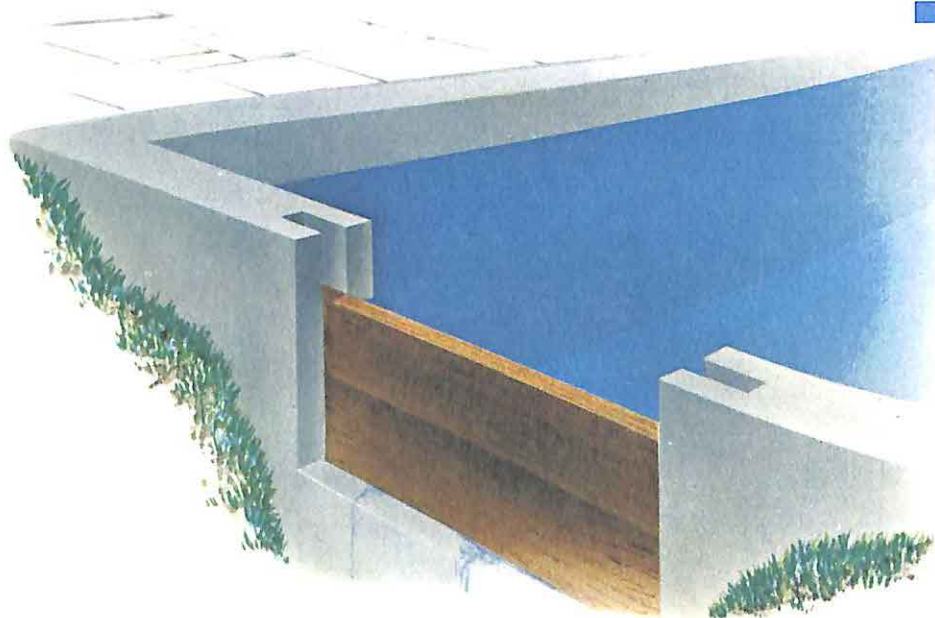
It can do work, however, only when the potential energy becomes the energy of motion. The rock's potential energy will be changed to kinetic energy if it starts rolling down the hill.

How can the wound spring's potential energy be changed into kinetic energy?

How would you change the potential energy in the water behind this small dam into kinetic energy? ■

B. In the Library

An important invention that uses the energy of moving molecules was the Pelton wheel. Do some research in the library to find out about this wheel and about the man who invented it. In what ways is the Pelton wheel similar to the steam turbine?



2. An Explosive Genie

According to an old story, James Watt conceived the idea for *his* steam engine from watching a boiling kettle when he was a small boy. What do you expect to happen to the kettle shown in the picture, which has a potato closing its spout? ● The water in the kettle is just starting to boil.

The cover on the kettle will bounce and rattle as the steam pushes it up. The steam exerts pressure on the lid of the kettle. What really happens is this: Heat from burning fuel increases the kinetic energy of the water molecules. The pressure or force on the inside area of the lid also increases. The rapidly moving molecules bump up and down against the cover of the kettle. Work is done as the kettle cover is forced to move. Remember the scientist's meaning for the word work (page 184).

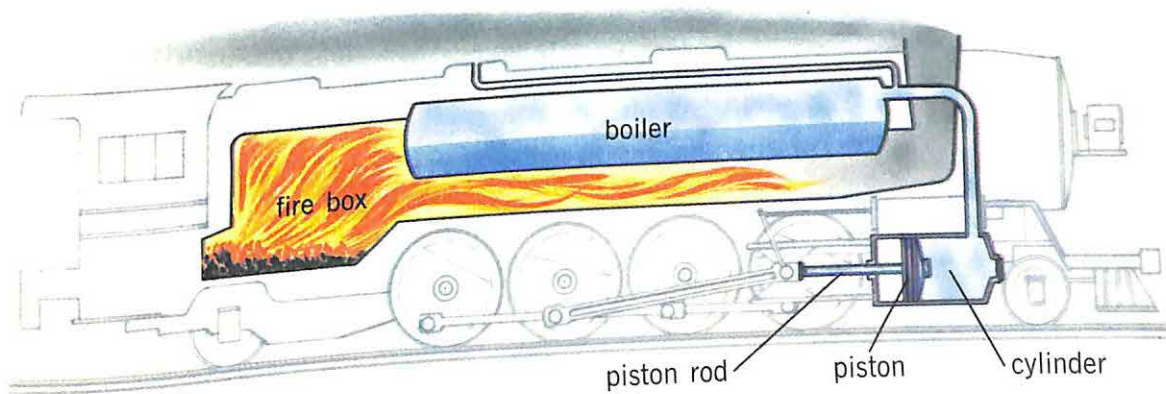
The energy of moving molecules can be harnessed to run a locomotive or any machine that can use the rapidly moving molecules of expanding steam. ▲ Expanding steam can do

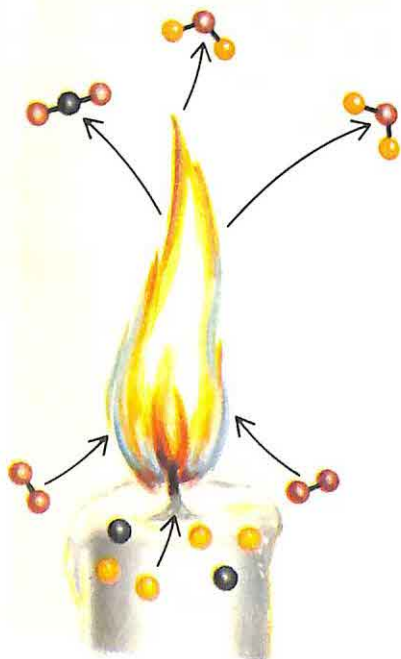
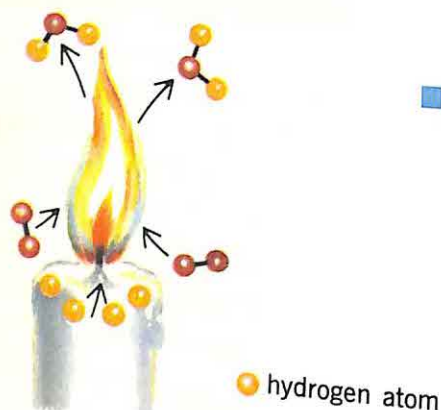
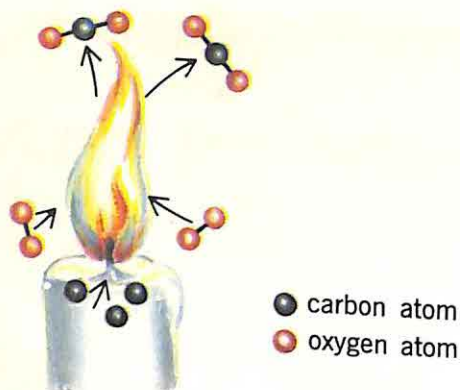


work. Steam to be used in a large engine is produced in a boiler, but such a boiler takes up a lot of space. Perhaps there is another way to get large amounts of work done and to do so by using a source of energy which does not take up too much space.

A Useful Explosion

When a substance explodes, its molecules of waste gases spread out extremely fast. The substance *suddenly* takes up a great deal more space, or at least tries to. The sudden expansion of some exploding substances can push walls aside and





splinter glass; but such an explosion can be controlled to do useful work.

There are some compounds that explode easily and the explosions can be controlled. One is gasoline for the family car. Gasoline is *very dangerous* when near a flame, but it can be exploded safely inside an automobile engine.

When gasoline explodes, it is burning very rapidly in a closed space.

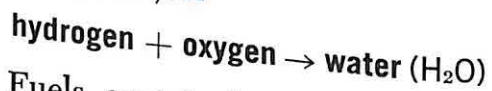
What really happens when gasoline burns, or explodes? You can get the answer by watching the burning candle in the investigation on the opposite page.

Energy from Burning Fuel

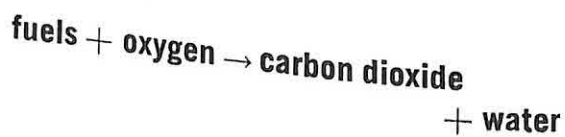
Candle wax is a **fuel** containing carbon and hydrogen. When the candle burns, carbon from the wax combines with oxygen from the air to form carbon dioxide gas. ■



At the same time hydrogen from the fuel (wax) also combines with oxygen from the air to form water vapor (H₂O). ■



Fuels contain hydrogen and carbon; so, whenever a fuel burns, carbon dioxide and water vapor are produced. Both carbon dioxide and water vapor are gases. Gasoline, or wood, or coal, when burned, will produce these two gases.



AN INVESTIGATION into What Happens When a Fuel Burns

Needed: a candle; a pie plate; a quart jar; limewater; a small glass

Light the candle and carefully drop some wax on the pie plate. *Be careful to keep your hand away from the flame.* After several drops of wax have fallen, quickly blow out the flame and set the bottom of the candle on the soft wax. Hold the candle in place until the wax hardens. Then place a small glass of limewater near the candle.

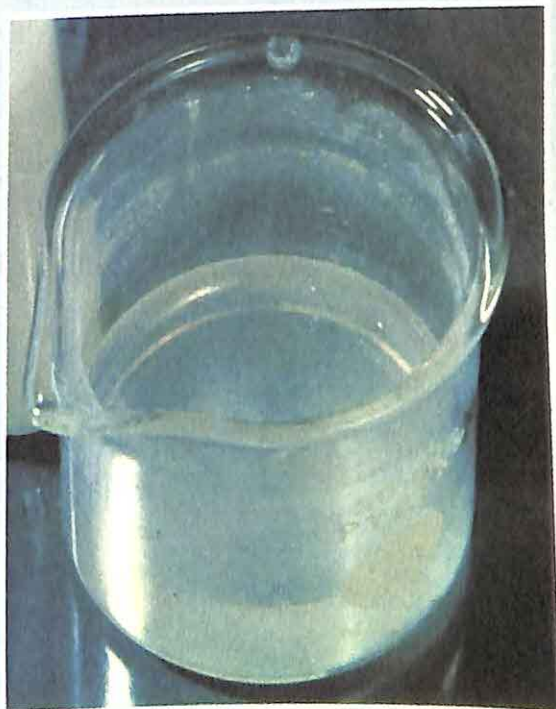
Without lighting the candle, place the quart jar over the candle and limewater for a short time. Are there any changes in the limewater?

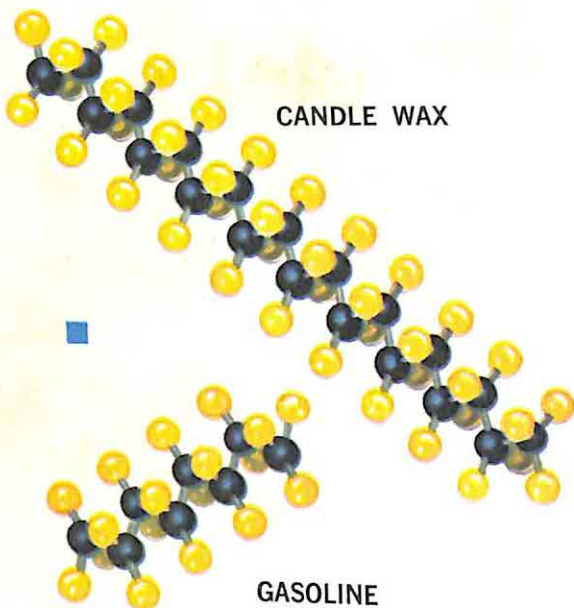
Remove the jar and light the candle. Then replace the jar over the candle and glass of limewater. ■

Watch closely as the candle burns. Can you see droplets of water forming on the inside of the jar? Where does the water come from?

After the flame goes out, let the jar stand in place and watch the limewater for several minutes. Move the pie plate gently back and forth as you watch. What happens? ● What do you think is present to change the limewater?

Additional Investigation: Are carbon dioxide and water produced when other fuels burn? Try burning some wood shavings on the pie plate to find out whether they do or not.





Candle wax and gasoline both contain carbon and hydrogen. But a molecule of gasoline is different from a molecule of candle wax. The picture of *models* of molecules shows you the difference between a molecule of candle wax and one of gasoline. ■

Gasoline burns much faster than candle wax. Yet when a molecule of gasoline or a molecule of wax burns, the same two gases are formed:

carbon dioxide (CO_2)
water vapor (H_2O)

These gases are formed when any molecule containing carbon and hydrogen is burned. Oxygen combines with the carbon and hydrogen to form CO_2 and H_2O .

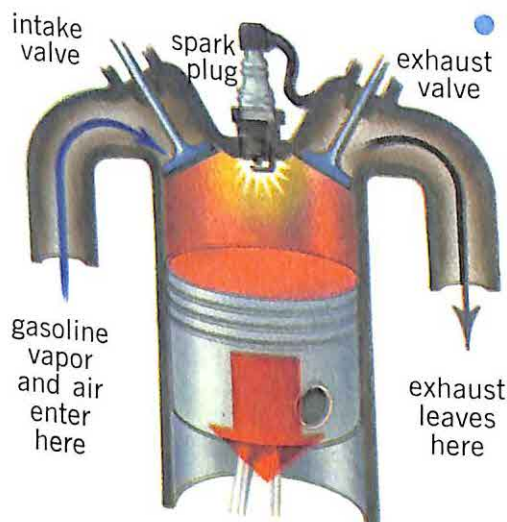
Gasoline has potential energy, another name for stored-up energy. When gasoline explodes, its potential energy is changed into kinetic energy,

the energy of motion. The kinetic energy of moving molecules can be used to do work.

When gasoline burns, the molecules of gasoline suddenly burst apart and the pieces rapidly combine with oxygen. The reaction is an explosion. The molecules from the suddenly exploded gasoline (mainly, gases) push outward. The pressure increases as the gases try to expand. Expanding gases can do a great deal of useful work. How?

Exploding Gasoline in a Tube

In most automobiles, liquid gasoline is changed into a vapor (a gas) in the **carburetor** (kär'bə-rā'tər). Here, as the gasoline evaporates, the vapor is mixed with air. The mixture of gasoline vapor and air then goes into a closed metal tube called a **cylinder** (sil'in-dər). ● Inside the cylinder is a piston. Gasoline vapor in the cylinder is ignited with a *spark*, which jumps across a gap on the **spark plug**.

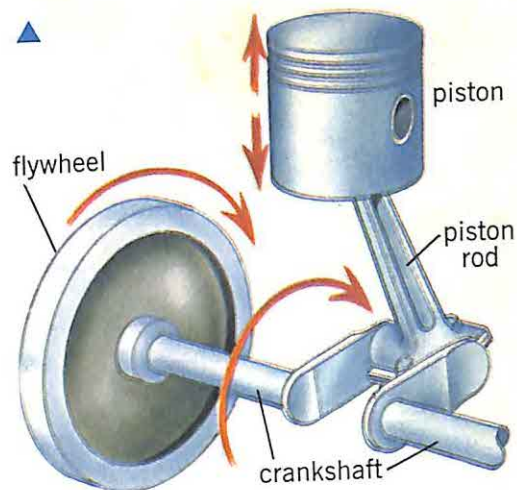


The spark explodes the mixture of gasoline vapor and air. Hot exhaust gases expand and exert a force that pushes the piston. The piston turns a wheel, as shown in the picture, and does work by moving a car, a truck, or a machine.▲

Next time you have a chance, ask an adult to show you what is under the hood of a car. Look for the spark plugs on the engine. How many cylinders does an automobile engine have? You can tell by counting the number of spark plugs.

You cannot see the cylinders, because they are inside the engine. There are usually four or more in cars, buses, or trucks.◆ The gasoline engine works because gasoline vapor and air are exploded in the cylinders. The resulting gases expand from the rapid increase in kinetic energy and are used to move the pistons.

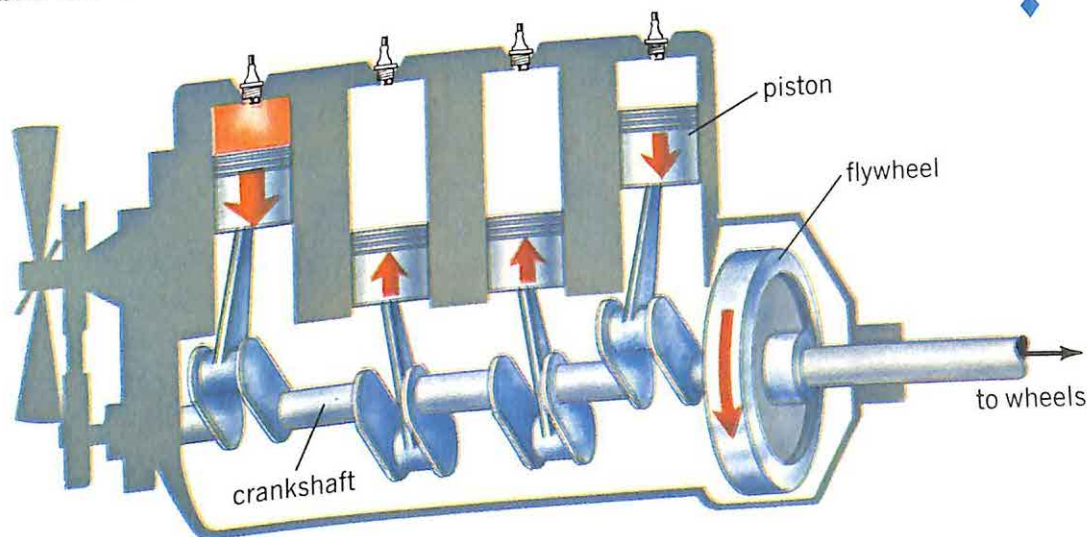
By learning how to use the kinetic energy in expanding gases, scientists have harnessed a powerful "genie."

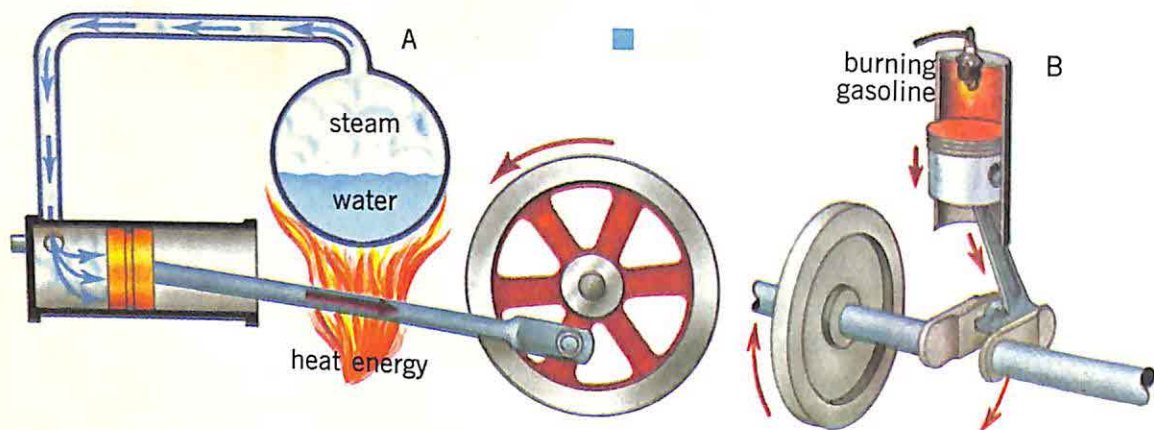


The concept behind our modern genie is simply stated: *Energy can be changed from one kind to another and transferred from one place to another.*

Two Kinds of Change and One Goal

The idea behind the work of a steam or gasoline engine has been to get the molecules of a substance to move very fast. They produce a force, a push. The force moves the wheels of an automobile, a locomotive, or a factory machine. Work is done when





the force of moving molecules moves an object (a car, a locomotive) through a distance.

The molecules in the steam and the molecules in the gasoline explosion were caused to move by different methods even though the outcome was the same—to exert a force. Really, two kinds of change took place.

In one kind of change, water was heated and changed into steam; but water and steam are the same substance. ■ Both are forms of water. (The formula is H_2O .) The difference between water and steam is a difference in *form* or *state*. Molecules of steam are farther apart and thus take up more space than molecules of water. Steam can be changed back into water by cooling it. This kind of change is a **physical change**, or what is called a change of state of the same substance. The rapid change from a liquid (water) to steam, a gas, causes the substances to expand and by expansion, to exert a force.

When gasoline burns, however, different substances are produced; the molecules themselves are changed.

Molecules of carbon dioxide and water vapor are formed. This is not a physical change but a **chemical change**. In a chemical change the molecules themselves are changed. Molecules of carbon dioxide and water vapor are not the same as molecules of gasoline and oxygen.

A chemical change takes place when coal or oil is burned to furnish heat to boil water; but this takes place outside the engine itself, in a firebox, perhaps. The only change inside the steam engine is a *physical change*—water to steam. On the other hand, a *chemical change* takes place inside the gasoline engine.

Either physical changes or chemical changes can cause particles to move. The physical change from water to steam increases the kinetic energy of the water molecules. The chemical change, in gasoline vapor and air, also causes an increase in the kinetic energy of the molecules. Physical and chemical changes can cause molecules to do work as they push against objects and make them move.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A steam locomotive can harness the kinetic energy of
 - a. molecules of water
 - b. hydrogen and oxygen gases
2. When gasoline explodes, its molecules
 - a. remain the same
 - b. break apart
3. When water boils, the change is a
 - a. physical change
 - b. chemical change
4. When gasoline explodes, the change in its molecules is a
 - a. physical change
 - b. chemical change
5. Gasoline and candle wax both contain
 - a. carbon
 - b. oxygen

B. Write a paragraph or two on this topic: Putting Molecules to Work.

**USING WHAT
YOU KNOW**

Below is a puzzle box made of strong steel. ● Fuel oil is being poured into the funnel. Water vapor (a gas) and carbon dioxide (a gas) are coming out the other side.

What must be happening inside the box? Do you have a “machine” at home that operates in a manner similar to this? Do not say “no” until you have given it some thought.



3. Balloons and Planes— Going Up

Fill a balloon with helium, and it will rise. If it is large enough, it can even carry a man with it. Do you know why? Helium is lighter than air. A balloon full of helium weighs less than an equal volume of air. The lighter balloon rises and floats on the heavier air. Will a balloon filled with ordinary air rise?

Fill a balloon with the air exhaled from your lungs. Will the balloon rise or not?

One thing is sure, however; a balloon filled with air will rise in and float on water. The reason is that the gas (air) is lighter than the liquid (water).

The principle of balloon flight is fairly simple. Fill the balloon with a gas lighter than air, and it will rise and float on the heavier air. (At some point, the balloon may reach a height where it weighs the same as the same volume of air outside and the balloon will not rise any higher.) The larger the balloon, the more men and objects it will be able to carry aloft.

An airplane with an engine is different from a balloon filled with helium; it is heavier than air. What makes it possible, then, for a plane to rise in the air? The engine, which moves the plane forward, makes it possible. On planes with propellers, the gasoline engine turns the propeller, which moves the plane forward. The backward motion of the air from the pro-

peller produces a forward motion of the airplane. In jet engines the thrust of the engine moves the plane forward. As the plane moves forward, the air molecules flow past the wings. Most of the **lift** on a plane is caused by reduced pressure on top of the wing as air travels over the curved upper surface. The increase in speed of the molecules of air results in a loss of pressure. The lower pressure above the wing and the higher pressure underneath makes the plane rise. To understand how this may happen, do the investigation on the opposite page.

An Explanation

Did it seem strange to you that the apples moved together instead of moving apart when you blew air between them? The result with the Ping-Pong ball seems even more unusual. The force of gravitation is pulling down on it and the air blast from above seems to be pushing down on it as well. Was the air really pushing down on the ball? It is important to understand just what forces were acting upon the apples and the ball.

A *force* is a push or pull that can change motion. A force must be applied to move a stationary object. When you blew between the apples, what force pushed them together? What force pushed the Ping-Pong ball against the inside of the funnel?

One substance surrounded the apples and that substance is air. Before you blew on the air between the

AN INVESTIGATION into a Mysterious Push

Needed: two apples; a bar, or rod, from which to suspend them; books or some object to hold the bar up

a. Hang two apples on pieces of string, each about 2 feet long. Be sure to suspend the apples on the strings so that they are no farther than an inch or so apart. When the apples are hanging without movement, blow hard on the air between them. ■

Do you get the same result as is shown in the photograph? How far apart can you move the apples and still get this result?



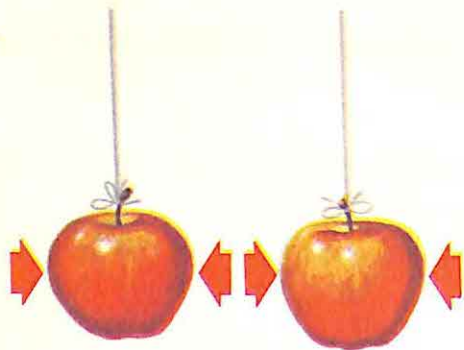
b. On the basis of what you have done with the apples, can you guess what will happen as you try to blow a Ping-Pong ball out of the funnel, as shown? ● Hold the Ping-Pong ball inside the upside-down funnel and blow hard through the spout. As you are blowing, take your hand away suddenly.

Try it.

What happens? Will blowing harder force the ball out of the funnel? Will blowing easier do it?

How do you explain your results? What have these results to do with the flight of an airplane?





apples, they hung straight down from the bar. This means that the air around them was pushing on them *equally* from all directions. ■ That is, the *pressure* of air around the apples was the same in all directions.

Blowing air between the apples caused them to move toward each other. This happened because the pressure between the apples was lowered. ■

The air pressure was lowered between the apples, but remained the same on the outside of the apples. The unequal pressure, the higher pressure on the outside of the apples and the lower pressure between them, pushed the apples together. In other words, the air around the outside of

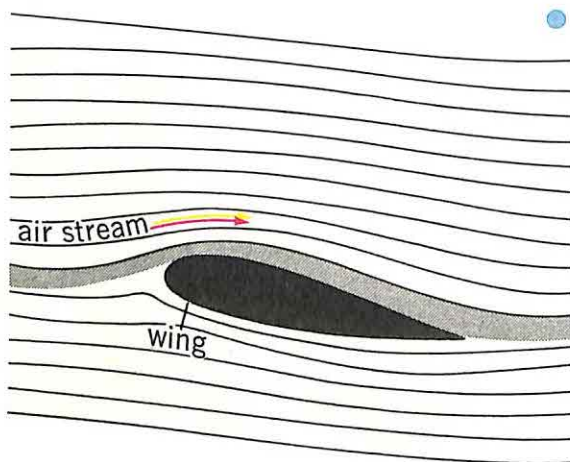
the apples was still. The air between the apples was moving because you blew on it. Because it was moving, the air between the apples had a lower pressure.

The pressure inside a region of air is lower when the air is moving than when it is standing still.

The scientist, Daniel Bernoulli, spent many years studying the effects of moving **fluids**, such as water. A fluid is any substance that flows easily. Liquids and gases are fluids. Air is a mixture of gases and thus is fluid. He found that the faster a fluid moves, the lower is its pressure. Bernoulli's discovery is very important. What does it have to do with the flight of an airplane? ● A great deal, but Bernoulli's principle is by no means the whole story. The investigation on the opposite page will tell more of the story.

An Airplane Flies

Examine the diagram of the airplane wing. ● Notice that the upper part, or surface, is curved, and that



AN INVESTIGATION into Flight from Da Vinci to Goddard

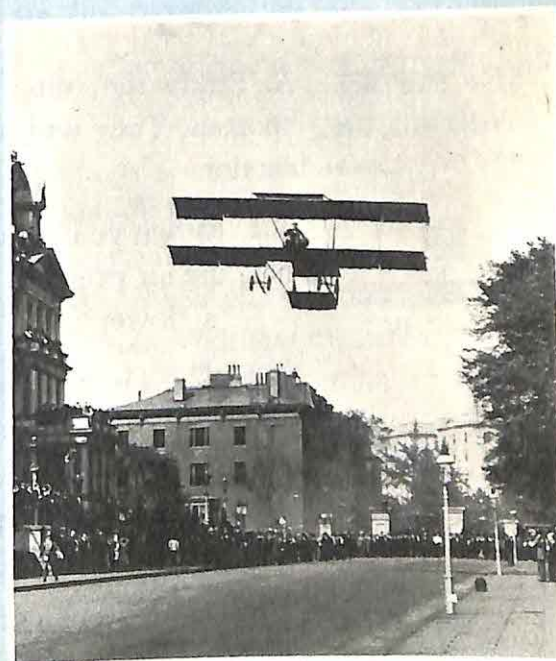
Needed: an adequate library

The pictures show two interesting moments in the history of flight. The top picture shows an early balloon made by the Montgolfier brothers in France. ■ The picture on the bottom shows an early airplane flight made by Claude Grahame-White on October 14, 1910. ● Men have dreamed of flying for a very long time. Even the Greeks had a myth about a father, Daedalus, and his son, Icarus, who flew with the wings they had made. Do you know the legend of Icarus? Look for it in an encyclopedia or other reference book.

This investigation is one into the way men's minds work. Start with the legend of Icarus and continue by investigating some of the real contributions that were made toward an understanding of flight by the following:

Leonardo da Vinci
Joseph and Jacques Montgolfier ■
Claude Grahame-White
Samuel Langley
Wilbur and Orville Wright
Robert Goddard

If possible, do the investigation in a library. Consult as many reference books as you can. Perhaps your teacher will want you to work with others in your class. Then you can share your findings.





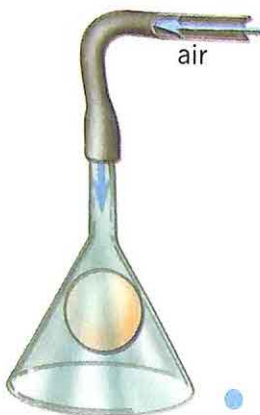
the lower surface is nearly flat. The air passing over the wing is squeezed between the wing and the air above. As a result, the air speeds up in order to get through the narrowed space. According to Bernoulli's principle, this increase in speed causes the air pressure above the wing to become less than the pressure below the wing.

In flight the wing also is tilted to point slightly upward (what might be called a climbing attitude or "angle of attack"). As the air flows under the wing, it strikes against the bottom surface of the wing that is in the way. This tends to force the wing upward, so the pressure on the bottom is greater. The difference in pressure is the lift; but remember that it is the forward motion of the plane that causes the air to rush over and under the wing. You will learn more about what causes the forward motion of a plane in the next section.

Try lifting the paper with your breath as the girl is doing. ■ Why does the paper fly up? Try explaining it any way you wish; but then try using Bernoulli's principle, which is: *The faster a fluid moves, the lower is its pressure.*

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.



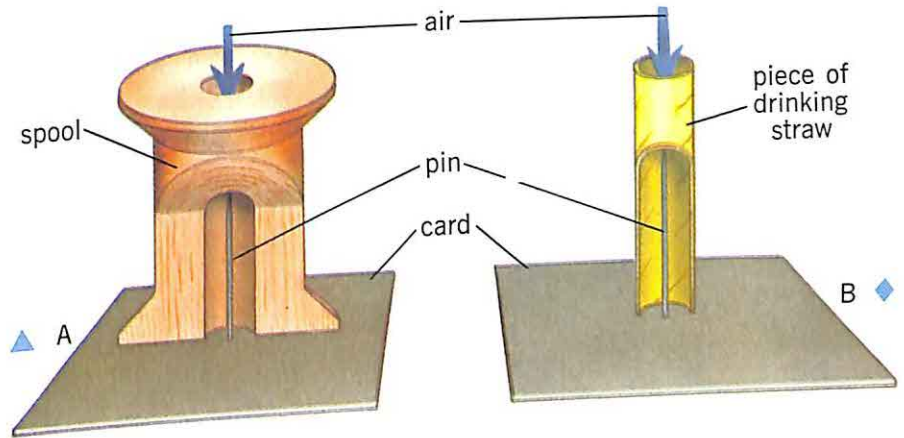
1. When you blew between the two apples hanging from a bar, the air pressure between the apples was
 - a. lowered
 - b. raised
2. The air pressure on top of the wing of a moving airplane is
 - a. lowered
 - b. raised
3. It is difficult to blow the Ping-Pong ball out of the funnel because the air pressure on top of the ball is ●
 - a. greater than that on the bottom
 - b. lower than that on the bottom

B. Write a paragraph or two on this topic: How Can a Heavy Airplane Rise into the Air?

**USING WHAT
YOU KNOW**

Try this investigation to test Bernoulli's principle:

Place a pin through a small card about 2 inches square. Hold the card and pin under an empty spool, as shown, and blow through the hole in the spool. While blowing, remove your hand from the card. ▲



Repeat the same investigation using a short drinking straw instead of the spool. ◆

The problems posed by this investigation are:

1. How will the card react each time a fast current of air passes over it?

2. Will it react differently when placed under the straw than when it is under the spool?

Before you do the investigation develop a hypothesis about what will happen when the card is placed under the spool and air is blown through the hole. Will this result be different from what happens when the card is placed under an air blast from the straw?

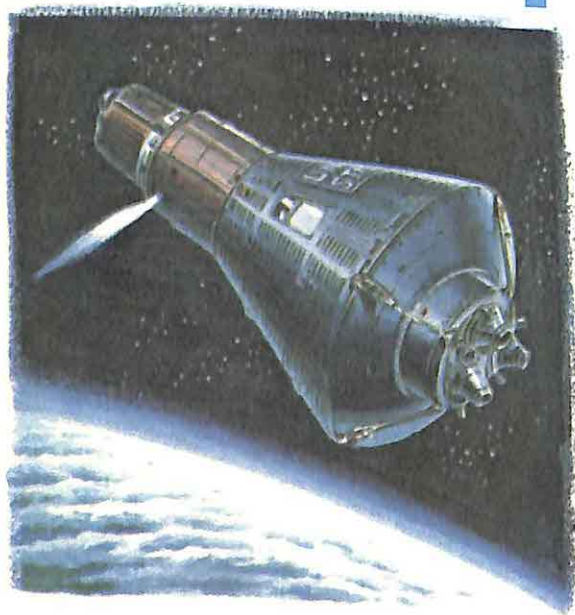
In forming your hypothesis you can draw on the knowledge of Bernoulli's principle you now have gained through the investigations with the apples and the Ping-Pong ball. You can also draw on your knowledge, gained from reading the text, of what makes an airplane fly.

4. Jets and Rockets

Look again at the picture of Hero's engine on page 203. Notice that it was turned by two jets. In addition to being the first steam engine, it was also the first jet engine.

Hero was far ahead of his time. If he could visit us today, he would see the principle of his engine in wide use.

Blow up a balloon and then let it go. It flies. It is a kind of jet engine. A stream of moving air molecules rushes out of the neck, and the balloon flies in the opposite direction. An action in one direction (the push of the jet) causes a movement in the opposite direction. This is an example of the application of another great concept, Newton's Law of Action and Reaction. It states: *Every action has an equal and opposite reaction.* Let us examine how this concept is applied in space flight.



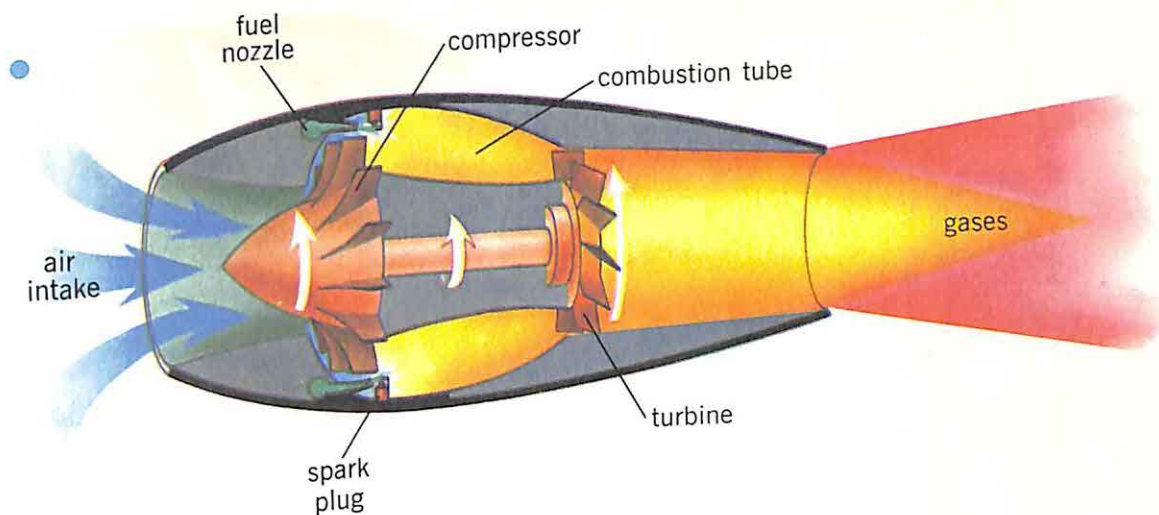
Imagine yourself out in space, perfectly safe in a pressurized suit. Suppose you want to move to your right. Then you must send a jet of moving particles to the left. Any **action** in space will produce an equal and opposite **reaction**. You may not recall how a space capsule is turned. Look at the picture. ■ The astronaut fires some small jets. Suppose he fires the jets toward the left (of the page). In which direction would his capsule go?

A Jet Plane Takes Off

Most of the high-speed planes of today are propelled by powerful jet engines. In addition to being powerful, the jet engine is so efficient that engineers are now designing smaller ones to replace the piston engine in automobiles.

A jet engine has no cylinders and no pistons. Think of it as a tube. At one end, air mixes with a fuel, such as kerosene. The fuel and air mixture burns and expands inside the tube. Fast-moving molecules blast out the rear (action), and the plane moves forward (reaction).

What is inside a jet engine? The picture shows one type. ● Study it carefully. Notice this one has two wheels with many blades, similar to the blades on an electric fan. The first wheel acts like a pump; it is called a **compressor**. The compressor forces air from the front toward the back of the tube. That is, it compresses the air. Kerosene is squirted into the com-



pressed air, and a spark plug ignites the mixture. It burns very rapidly with a roaring flame. Heat increases the kinetic energy of the molecules. As the kinetic energy increases, the gases expand and exert a force.

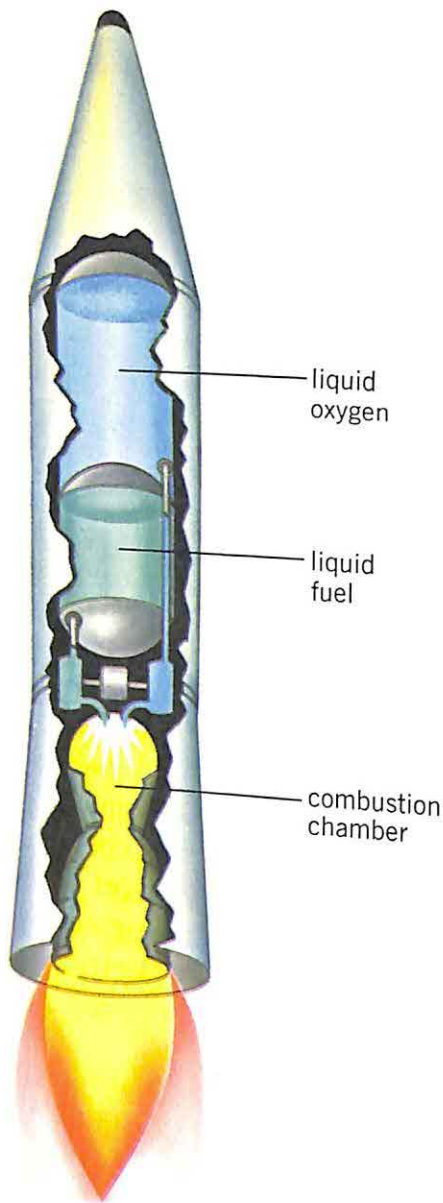
The moving molecules cannot shoot out the front of the jet because the compressor keeps pushing air in. They shoot out the rear of the engine (action); and the jet moves forward (reaction); and the jet moves forward (action). The fast-moving gases also turn a bladed wheel as they flow toward the rear. The second wheel in the picture is a turbine. A shaft is attached to the turbine. It turns the first wheel, which compresses the air.

The air must be compressed if the burning of the kerosene is to produce enough force to move the plane. The kerosene keeps squirting in and burns, and the exhaust gases blast out the rear. The turbine keeps turning, and with it, the shaft. The shaft turns the compressor which keeps forcing air in, and the blast of hot gases from the rear forces the jet forward.

The explanation of how a jet engine works seems simple enough, but if you read it carefully you may have become aware of one problem. If the air must be compressed before the engine will work, and the engine must be moving to work the compressor, how does a jet engine get started? The answer is that a jet engine cannot start by itself. A small electric starter engine turns the compressor before the fuel is ignited.

As the jet plane moves forward, molecules of air rush rapidly over the upper surface and under the lower surface of the wing. With the wing tilted slightly upward, the air pressure on the upper surface of the wing is reduced, and the greater air pressure striking the lower surface of the wing lifts the plane up. The jet plane rises. Bernoulli's principle may be used to explain this action.

Jet engines need oxygen to combine with the kerosene for the kerosene to burn. Those that use the oxygen in air are useless out in space.



Rocket engines, however, carry their own supply of oxygen with them. They can go out into space where there is no air. ■ The *action* of the blast of moving molecules from the rapidly burning fuel causes a *reaction* that pushes the rocket through space. Note that the jet blast of burning fuel moves the rocket ahead in a straight line. ● The *action* of the



burning fuel in one direction creates an equal *reaction* that moves the rocket in an opposite direction.

A Rocket Blasts Off

Every action has an equal and opposite reaction. The blast from a rocket is downward (*action*). The rocket goes up (*reaction*).

Suppose the rocket has four stages, like the one on the opposite page. ▲ The load (sometimes called the payload) of instruments or passengers is carried in the fourth stage. The first stage carries enough fuel to move the rocket high into the atmosphere. It drops off to reduce weight. Then the second stage, the booster, takes over.

After the fuel in the second stage is used up, the booster drops off and the third stage takes over. The blast from each stage gives the rocket still more speed and boosts the rocket still farther into space.

The fourth stage of the rocket may have instruments in it. It may be a man-made satellite designed to revolve around the earth or it may be a spaceship with a pilot inside.

The rocket might carry a liquid fuel and liquid oxygen. The fuel and the oxygen combine to give the rocket a powerful thrust *forward* as the blast of moving molecules of gas roars *backward* out of the rocket tube. Rockets may use different kinds of fuels. Some rockets use a solid fuel.

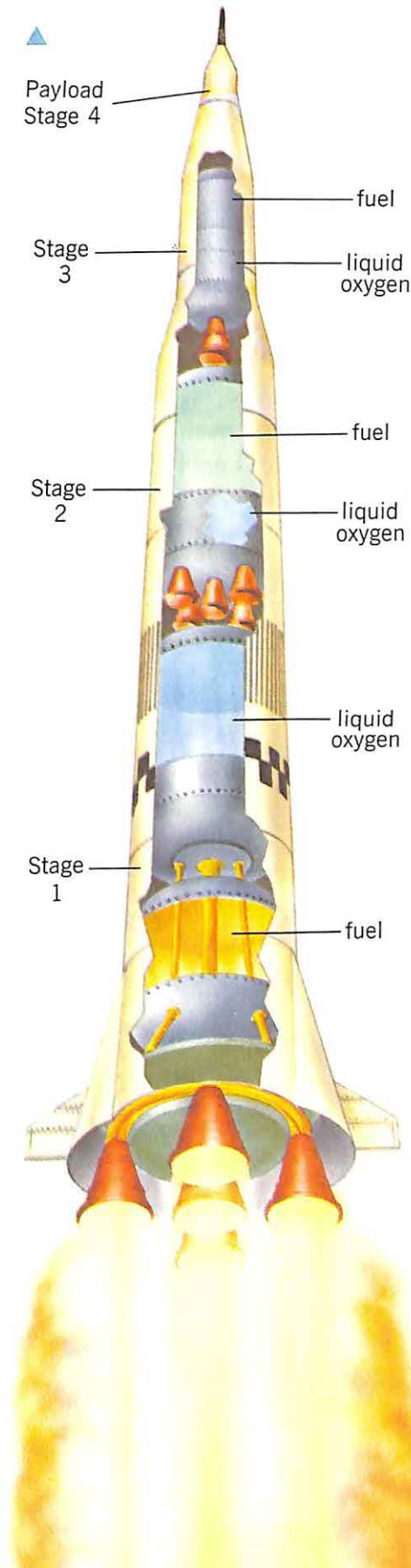
Suppose a spaceship has a pilot in it or, perhaps, an entire crew. Suppose they are on their way to the moon. When the rocket leaves the earth's atmosphere and gets into outer space, the pilot must be able to control his spaceship. This is important in case something goes wrong with the automatic control system.

As the rocket approaches the moon, it will be pulled by the moon's force of gravitation. What will happen? At the tremendous speed of the rocket, the pilot could crash into the moon.

How will it be possible for astronauts to land safely on the moon and later be able to return to earth?

The explorations are being carried on now. You may wish to keep a notebook on each exploration (Apollo, Gemini, and others) as they are carried out. Many experiments are planned before a man can land on the moon.

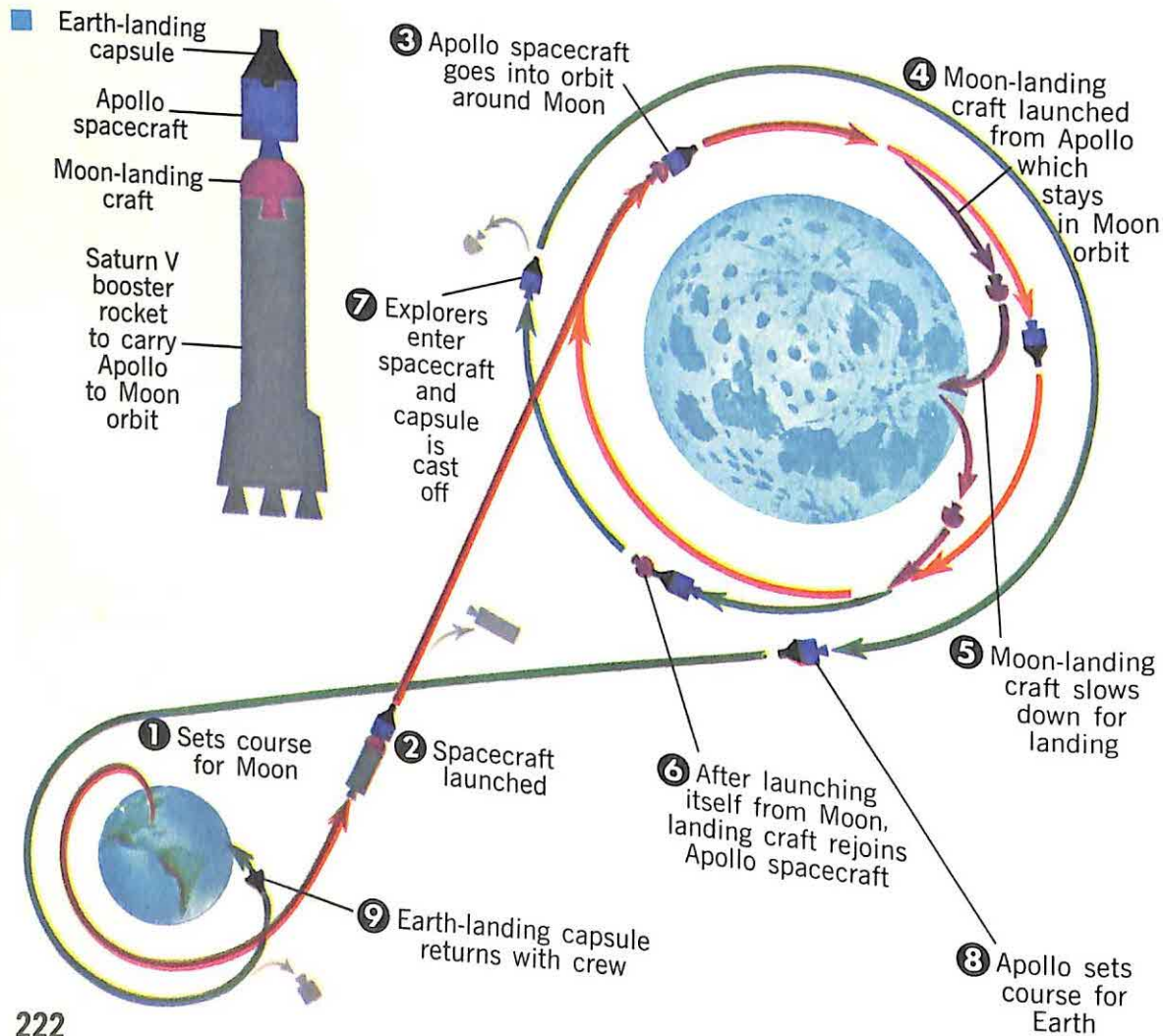
One plan is to use a landing capsule carried to the moon by an Apollo spacecraft. This plan is called LOR (Lunar Orbital Rendezvous). When the spacecraft comes close to the moon (100 miles above the surface), it releases a small landing craft. The landing capsule curves closer and



closer to the moon's surface, while the Apollo continues to orbit. To keep from crashing into the moon, the astronaut in the landing craft fires a rocket so that the blast pushes against the moon's gravity. This should slow the capsule down so that it will "soft-land" easily on the moon's surface. To return to the earth, the landing capsule will take off and rejoin the Apollo still in orbit around the moon.

To understand each step, study the diagram carefully. ■ Be sure to notice the color and shape of each part of

the giant spaceship and to follow the numbers in their exact order. The symbols show you which part of the spaceship is participating in each step. The colored arrows show the various courses that will be taken. The red arrows show the course from earth to the moon. The purple arrows show the course of the craft that lands on the moon; the orange arrows show the orbit of the Apollo around the moon; and last, the green arrows show the Apollo's course back to earth.



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The motion of Hero's jet engine may be explained by means of
 - a. Bernoulli's principle of reduced pressure
 - b. Newton's law of action and reaction
2. The flight of rockets in space can best be explained by
 - a. Newton's law of action and reaction
 - b. Bernoulli's principle of reduced pressure
3. Rockets are different from jet planes because they
 - a. need oxygen for flight
 - b. carry their own oxygen
4. When a jet engine is operating at full speed, the
 - a. turbine is turning the compressor
 - b. compressor is turning the turbine
5. A spaceman, dressed in a pressure suit, steps out of his spaceship into space. He shoots his jet gun to the right. A stream of molecules rushes in that direction. The spaceman moves to the
 - a. left
 - b. right

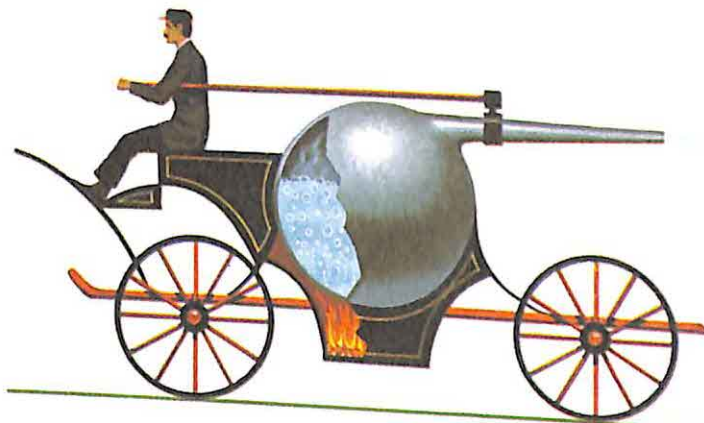
B. Write a paragraph or two on this topic: Jets and Rockets.

**USING WHAT
YOU KNOW**

1. Suppose one of your friends made this statement: "Let some of our rockets carry jet planes to the moon. Other rockets could carry the fuel. Then our jets could take off from the moon."

Would this be possible? What is the reasoning behind your answer?

2. A squid (a relative of the octopus) is able to move quickly through the water. It squirts a jet of water into the water around it. Describe how a squid could move with this method. Suppose it squirted water directly behind it, where would it go?



ON YOUR OWN

Many years ago, Sir Isaac Newton designed this car (see the illustration) to demonstrate the law of action and reaction. ■ The car did not work.

Could you design a car or cart that does work by jet propulsion? Try it! One girl mounted the nozzle of her garden hose on the back of an old doll carriage. A boy made another model cart using tiny CO_2 cylinders that he was able to purchase at a hobby shop.

5. The Main Concept: The Use of Moving Molecules

Long ago man could do only as much work as his muscles allowed; they were his source of "push and pull." He could lift and tug and haul. The energy from the food in his body was the only energy he could use. Later he learned to use animals to work for him. He began to modify and improve his environment by inventing new things.

Still later, he learned to use simple machines: the lever, the pulley, the wheel and axle, the inclined plane, the wedge, and the screw. With simple machines he could multiply force; but

he could get no more work out of a simple machine than he put into it. He needed a source of power. To add to his own power man needed new sources of energy. He first learned to use the energy of wind and water and, still later, fuels.

Man learned to use fuel as a source of energy to do work. In burning, the fuel combines with oxygen. The *heat* of the burning fuel was used to increase the motion of the molecules of water. The result was that the water expanded—and became steam. Gasoline and kerosene, too, combine with oxygen to produce gases that expand suddenly. Expansion furnishes the force to do work.

The energy in fuels can be traced back to the molecules in the fuel, in gasoline, for instance. When these molecules burn, heat is produced which causes gases to expand rapidly. When burning gases are trapped in a cylinder that has a movable piston, they can do work. They can push a piston or push a jet. By putting them to use, man has increased the energy available at his command.

Once he had learned to use the force of moving molecules, he was able to do much more work.

The concept is simple: moving molecules in expanding gases can be used to do work. They can push a piston; they can turn a turbine. Finally, man learned that moving molecules forced out the back of a jet plane could push the plane forward at a high speed or could push a rocket into space! The concept behind this phenomenon is that *for every action there is an equal and opposite reaction*. By understanding the concept man moves forward in his effort to control his environment and to reduce his limitations—especially those of ignorance.

Man learned that the kinetic energy of molecules increases as they are heated; they tend to move farther apart. With this understanding of the kinetic energy of molecules, man is now able to move into space.

He can do so because he has discovered, for one thing, that matter can release energy, energy that has been stored in the matter. Energy

can be changed from one kind to another. *Potential* (stored-up) *energy* in matter can be changed into *kinetic energy* (the energy of moving objects or particles). The *kinetic energy* of molecules of a gas can push a piston or turn a wheel.

As man learned to release the stored-up energy in fuels, he learned to get more work done in much less time. He could use the time saved from human labor to do other things, things that he enjoyed doing. He found time to read, to write, and to think. He was able to give more time to art, to music, to literature, and to science.

There is a great need for scientists, as there is a great need for engineers. But there is not only a need for scientists and engineers; there is a great need, as well, for artists, for musicians, for writers, for teachers. There is a need, too, for carpenters, lawyers, doctors, and laborers to accomplish all the work that men and women must do.

The world is so full of a number of things that it needs the cooperation of men and women of all abilities and skills; there is a need for everyone. What do you hope to be or do?

There is no need to rush to make up your mind. As you go on in school, look about you. Find out what you like to do and what you can do best. This is a world in which science plays a great part. No matter what your interests may be, you will find your place in it.

Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts in this unit by doing these problems.

1. In the summer, especially on a hot day, the air inside the tires of automobiles expands. Some air has to be let out. In the winter, they go down a bit; so air has to be added.

How would you explain this?

2. a. A turbine, in a steam turbine engine, whirls as the molecules of hot steam hit it.

b. A turbine, in a jet plane engine, whirls as the molecules of exhaust gases from burning kerosene hit it.

What is the difference in the kinds of changes the molecules undergo in (a) and in (b)?

3. Bob noticed that the shower curtain on a stall shower moved in when the water was turned on hard. How would you explain this?

4. Joan threw a basketball while she was standing on roller skates. She noticed that, as she threw the ball forward, she moved backward slightly.

How would you explain this?

5. Below is a list of some well-known kinds of engines. Try to determine which are *internal combustion engines* (fuel burned inside the engine) and which are *external combustion engines* (fuel burned outside the engine).

jet engine

auto engine

Hero's engine

piston steam engine

6. Which of these items are examples of *kinetic energy*?

a wound clock spring

logs rolling down a hill

an unexploded stick of dynamite

a high fly to left field

7. Check your understanding of the main concepts in this unit by using each of these key terms in a sentence that makes sense.

molecules	chemical change
potential energy	Bernoulli's principle of reduced pressure
kinetic energy	Newton's law of action and reaction
physical change	energy or force

A PROJECT TO DO

In the next ten years men will try to reach the moon. Keep a notebook entitled: *Operation Moon*. In a sense you will be writing your own book.

Keep a record of each stage in the project. For instance,

- The development of a powerful rocket
- The first flights to explore the moon (Ranger, and others)
- The first flights of Gemini, the spaceship that can carry two astronauts.

Keep maps of flights, especially of the orbits of the rockets and spaceships.

FOR YOUR READING

1. *Spaceflight and How It Works*, by William P. Gottlieb, published by Doubleday & Co., Garden City, 1964.

There are good photographs by the author in this book and good explanations of why aircraft fly.

2. *Rockets Into Space*, by Alexander Crosby and Nancy Larrick, published by Random House, New York, 1959.

The authors discuss rockets, satellites, spaceships, space stations—and getting a man to the moon.

3. *Off Into Space!* by Margaret Hyde, published by McGraw-Hill, New York, 1959.

The principles behind space travel are discussed. The place of gravity, atmosphere, and the principles of rocket travel are among the important topics in this book.

4. *Jets*, by Charles Verral, published by Prentice-Hall, Englewood Cliffs, New Jersey.

This book is about jets and the principles of jet propulsion.

A. Over two hundred years ago when men were still crossing the ocean in sailing ships, Sir Isaac Newton was developing formulas that had to do with rockets traveling in space. He was truly a man living ahead of his time. He was so far ahead of his time that he found it necessary to develop a new kind of mathematics in order to complete his calculations. He called his new mathematics *calculus*.

On the basis of his results, Sir Isaac made these predictions.

1. In order to stay in orbit around the earth a satellite would have to achieve a speed of 5 miles a second.

How many miles per hour would this be?

2. In order to escape the earth's gravitational pull altogether, a rocket must achieve a speed of 7 miles per second.

How many miles an hour would this be?

Were his predictions correct? Investigate by visiting the library and looking through some up-to-date books on space travel.

B. Try to invent a mathematical formula for measuring the amount of work you do. A mathematical formula is a short and simple way to explain something. It is shorter than a sentence.

For example, let us express this next sentence in a mathematical formula. *To find the area of a rectangle, multiply the length by the width.*

First choose a symbol or letter to stand for each part of the statement. A can stand for *area*, L for *length*, W for *width*. The above sentence can now be written as a mathematical formula $A = L \times W$, or area equals length times width.

To find the area of any rectangle, use this formula. If L equals 4 inches, and W equals 2 inches, what is A (the area)? Did you say 8 square inches?

Now, how can you develop a formula for *work*?

To do *work*, you must move an object through a *distance*. To move an object, you must apply a *force*.

Suppose you lift a pound of sugar to a height of 1 foot. The force you apply is 1 pound. Suppose you lift the same pound of sugar to a height of 2 feet. You would still apply

the same force (1 pound). But you would be doing more work. How much more work? You are lifting the sugar *twice* the distance.

If you lift the pound of sugar to a height of 3 feet you are lifting it 3 *times* the distance. You are doing 3 *times* the work.

Does the term "3 *times*" give you a clue? What does "*times*" mean in arithmetic?

Try to fill in the blanks in the sentence below. If you can, you should have no trouble making a mathematical formula for *work done*.

To find how much *work* is *done*, ? the *force* needed to lift an object ? the *distance* it is being lifted.

What unit is used to measure *work done*? A combination of the units in the formula is used. For example, if you lift an object to a height of 1 *foot*, and apply a force of 1 *pound*, you are doing 1 *foot-pound* of work.

Derive a formula for *work*.

Clue: The formula will use three quantities:

work
force
distance

Now you are on your own.

CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

(Text pages 230–83)

UNIT CONCEPT

The amount of energy gotten out of a machine does not exceed the energy put into it.

A Preview of the Concepts

Unit Six

ELECTRONS IN ACTION

The pupils investigate how different forms of energy can build up charges on atoms (potential energy), how this energy changes to kinetic energy when electrons move, and how the force generated does useful work. They complete their investigation of energy changes and the means of transmitting forces.

A VIEW OF THE UNIT

Pupils often find that electricity, more than any other form of energy, is the most difficult to comprehend. It need not be so in the elementary grades. The concepts of energy build-up and transfer by means of other forms of energy and by machines are relatively easy to grasp. The technology of electronic inventions is more difficult. Proper understanding of their complexities requires many tools for fine measurement of minute quantities of energy and a grounding in advanced mathematics.

In the sections of this unit, pupils begin with the simple concept that charges can be built up on atoms by a transfer of electrons. Every pupil who has said “ouch” after getting a shock from static electricity knows that charges move. Electric charges get on an object when it is moved against a resistance; electrons “rub off” atoms, so to speak. But getting a spark is generally rather useless, unless the motion and direction of electrons can be controlled.

From generating an electric current from friction and from moving a coil of wire through a magnetic field (there’s resistance here, too), pupils investigate electric bells and electric motors—forms of electric machines that do work. The heart of each is, of course, the electromagnet that pupils build while they make operating models of a bell and a motor. After the electric bell, a kind of signaling device, the pupils investigate the telegraph and telephone. It would be unfair not to investigate how messages can travel without wires; this involves another kind of energy conversion, from motion of electrons to motion of electromagnetic waves. Pupils cannot be expected to grasp the technology of electronics; hence, only the general concepts are developed, we hope sufficiently so for reasonable comprehension. Strangely enough—or perhaps not—some pu-

pils become fascinated with electronics early and they can give information quite beyond what most of their classmates can comprehend. Teaching suggestions for this unit, coupled with additional explanation, are more extensive than for most other units so that you may guide interested pupils or stimulate them to pursue a fascinating subject.

SUPPLEMENTARY AIDS

All the films and filmstrips are in color. Those noted as "Junior High" are somewhat advanced, but useful. Names and addresses of distributors and suppliers are on page F-26.

Electrons at Work (14 min.), E.B.F., 1964. Electrons have mass. Electrons may be rubbed off one substance and transferred to another; objects with like charges repel; those with unlike charges attract. The movement of charges can be controlled and made useful. (Junior High)

Magnetic, Electric and Gravitational Fields (11 min.), E.B.F., 1964. Experiments depict how we know of magnetic, electric, and gravitational fields. Shows usefulness of this knowledge. (Junior High)

What Is Electric Current? (14 min.), E.B.F., 1964. Demonstrates the characteristics of electricity and its uses to produce light and heat and how it can do work in less time. (Junior High)

Sources of Electricity (11 min.), Cenco, 1964. Electricity used in homes and industry comes either from batteries—which are "chemical sources"—or from generators—which are "mechanical sources." Explains how each source develops electricity. (Intermediate)

Series and Parallel Circuits (15 min., sound), Cenco, 1964. Explains how, in order to use electricity, one must give it a path to follow. Series and parallel circuits are explained. Suggests how to wire circuits of each type, and the uses of each. (Intermediate)

Radio and Radar (12 min., sound), Cenco, 1964. Clear explanation of basic theory of radio and radar communication. (Intermediate)

Earth Satellites (12 min., sound), Cenco, 1964. Explains what a satellite is and how it stays in orbit. Tells of Soviet and American satellites and how their instruments radio useful information from space. (Intermediate)

Communication Satellites (12 min.), F.A., 1964. Communication satellites enable us to send radio and television signals around the earth. Some satellites bounce radio signals from the earth back to earth. (Intermediate)

What Is Static Electricity? (38 frames), Jam Handy, 1960. How static electricity is produced by friction, resulting in gain or loss of electrons; explains negative and positive charges. Gives suggestions for investigations into static electricity. (Intermediate)

What Is Current Electricity? (35 frames), Jam Handy, 1960. Defines current as a flow of electrons through a conductor. Electrical energy can be changed to other forms of energy: light, mechanical, heat, and sound. (Intermediate)

Films

Filmstrips

How Most Electricity Is Produced (35 frames), Jam Handy, 1960. How electricity is produced in turbo-generators; purpose of a conductor, galvanometer, and magnets. Suggests investigations with simple movable magnets and permanent magnets. Shows use of water power in hydro-electric plants; also future use of nuclear energy. (Intermediate)

Producing Small Amounts of Electricity (35 frames), Jam Handy, 1960. Difference between dry cell and wet cell; how each produces electricity; how electricity is measured and how heat energy and chemical energy can be changed to electricity. (Intermediate)

Electromagnets and How They Work (35 frames), Jam Handy, 1960. How to make an electromagnet; increase the strength of the magnet, and determine the poles. (Intermediate)

How Is Electricity Used in the Home? (35 frames), Jam Handy, 1960. Use of switches to open and close circuits; how many ways electricity is used in homes; making an electric bell; how an electric motor works. (Intermediate)

Using Electricity Safely (35 frames), Jam Handy, 1960. What causes a short circuit; general safety suggestions, both indoors and outdoors, in regard to electricity. (Intermediate)

Thomas Alva Edison (40 frames), Jam Handy. The story of Edison's experiments, his successes, and his contribution to our way of life. (Intermediate)

World's Energy Supply (37 frames), McGraw-Hill, 1962. Sun is main source of energy. Classification of energy—motion, heat, electrical, radiant, and nuclear. "Neither matter nor energy can be created or destroyed, but can be changed to other forms of energy." (Intermediate)

Starred (*) titles are especially recommended for their content and reading level. Names and addresses of the publishers are on page F-24.

**All About Sound and Ultrasonics* by Ira M. Freeman, Random House, 1961. Tells what scientists have discovered about sound and explains research on the frontiers of science. Some of the studies are trying to find better ways to control noise, others to improve underwater sonar, and still others to find more efficient methods of washing clothes and dishes. (Average)

Electricity: The Story of Power by Arnold Mandelbaum, Putnam, 1960. Describes history of the major discoveries and inventions of electricity. Includes the work of Gilbert, Galvani, Volta, Faraday, Morse, Edison, and DeForest. Provides not only a historical survey, but also consideration of important characteristics of electricity. (Advanced)

Electromagnetic Waves by Robert Irving, Knopf, 1960. The one form, light, visible to us is described in addition to the invisible waves. Included are radio waves, infrared rays, ultraviolet rays, X rays, microwaves, and gamma rays. All are described as messengers of the universe, whose messages scientists are learning how to read and interpret. (Advanced)

**Magnet* by E. G. Valens, World Publishing, 1964. Contains brilliant photographs that help explain simple investigations. Describes basic principles and uses of magnetism, and the magnetic fields of the earth and space. (Easy)

Satellites in Outer Space by Isaac Asimov, Random House, 1960. Explains how scientists use satellites to find out more about the earth, the moon, and outer space. Precise diagrams supplemented by photographs depict the satellites and their orbits, and help to describe such phenomena as the belts of particles around the earth. (Easy)

°*Sound and Its Reproduction* by Jerome S. Meyer, World Publishing, 1964. Describes wave motion, echoes, resonance, and other characteristics of sound, as well as the recording and reproduction of sound. Information about our sound recorder, the ear; and our sound producers, the vocal cords. (Advanced)

Sound and Ultrasonics by Robert Irving, Knopf, 1959. Simple investigations and illustrations explain the meaning, making, bending and bouncing, recording, transmission, and hearing of sounds. Musical scales and animal sounds are included. (Average)

The Story of Electricity by Mae and Ira Freeman, Random House, 1961. Describes how electricity works in flashlights and vacuum cleaners, in cars and factories, and in satellites orbiting the earth. Easy investigations are included. (Easy)

► INTRODUCING THE UNIT

One good way to start this unit is to allow time for pupils to read page 231 and examine the illustration. This photograph could not have been taken 90 years ago. The first electric light bulb was made by Thomas A. Edison on October 21, 1879. It was several years before an electric company started delivery of electricity from a central station. Suggest that the pupils think of something they have done in the last 24 hours that used some form of electricity, and then try to describe how they would have done the job without electricity. Electricity does work so easily! Why didn't people discover how to harness this useful form of energy sooner?

Section 1: "RUBBING" OFF PARTS OF ATOMS

The pupils investigate the production of static electricity and note that stored electric charges may attract objects or be made to flow through a conductor.

Introducing the Concept

A plastic sandwich bag can be used to start discussion. If you draw it briskly over a piece of wool or toweling, it will stick to a wall on a dry day. Better yet, after rubbing, lay it on a sheet of paper, so that you can return the sheet over with the plastic bag on the underside. Does this remind you of other experiences, such as pulling the plastic bag off a suit that has come from the cleaners or taking nylon or rayon clothing from

(Text pages 232-38)

SUBCONCEPT

A transfer of electrons from one object to another gives them potential energy; when the electrons move, they have kinetic energy.

Equipment and Materials

... plastic sandwich bag

an electric dryer? The plastic fabrics snap and crackle as they are pulled apart and they sway towards the door of the dryer or towards your clothing. Pupils may cite other instances of this sort of attraction and crackling with the production of a spark.

How can we make electricity? What is it? How can we make it do work?

Developing the Concept

Electricity from friction. Probably the best way to start is with the investigation on page 233. Instead of tissue, puffed rice grains or salt may be substituted. Deflecting a stream of water, as suggested, is more easily done if only a thin stream of water is allowed to run. A cool, dry day also tends to effectuate better transfer of electrons. Whether the objects are positively or negatively charged is of less importance for elementary pupils than the concept that there is a difference in charges.

After the pupils have read the explanation of their investigation up to "Static and Current Electricity," you may perhaps wish to recall that for two units we have been trying to get rid of friction. What force have we just used? (Friction.) Have we made it do work? (Yes. First we have moved electrons from the atoms of one substance to the atoms of another. Then we used the difference in charges to move a stream of water and to pick up bits of tissue or puffed rice.) How do we know work was done? (Objects are moved through a distance.) There has been a transfer of energy—or a conversion of energy from friction (mechanical force) to electrical attraction.

Pupils should see that there is greater attraction between oppositely charged substances than between a charged substance and a neutral substance. If they have difficulty, place

$$-10 \text{---} 0 \quad \text{and} \quad -10 \text{---} 0 \text{---} +10$$

on the chalkboard. How much greater is the charge in the second than in the first?

How can anything as small as an electron do work? To counteract the impression that the substance is charged, review pupils' concepts (or preconceptions) of the size of an atom. Let's imagine that the nucleus of an atom weighs 1,837 pounds, nearly a ton. The electron would weigh 1 pound. But perhaps 100 million atoms side by side would be needed to span 1 inch. Pupils should be able to infer that the individual atoms have a charge and that a very large number of atoms, indeed, supply the electrons that give a substance a charge.

What is the structure of the atom? For pupils who need a review of the structure of the atom, ask: Where are the positive charges located? Where are the negative charges located? Pupils recall that the charges are in balance. If we remove one electron, what is the charge now? If we add an electron, what is the charge? If a pupil asks why we move electrons from the outside of an atom rather than a positive charge from the nucleus, let

Friction may transfer electrons, giving objects an electric charge.

Processes emphasized

Investigation (with design of experiment)

Invention

Observation

Analysis of observation

Hypothesizing

Theorizing

Prediction

Testing

Electrons are extremely small.

Loss or gain of an electron gives an atom a charge.

him imagine that a nucleus has the size of a walnut; the nearest electron might be a half mile away. Also tell him that a change in the nucleus changes the atom and gives us nuclear energy, which will be studied in the next unit.

But do not give the impression that electrons are removed from individual atoms. Free electrons collect on substances; they are not rubbed off from the individual atoms.

From static electricity to current electricity. If you hold a book at arm level from the floor, the book has what kind of energy? (Potential—or stored.) If you let the book drop to the floor, what kind of energy does the book have? (Kinetic energy.) This kind of potential energy is due to the object's position. What kind of energy does water behind a dam have? What kind when it turns a wheel? We can think of an electric charge as a form of potential energy. As pupils read "Static and Current Electricity," they should infer that lightning is a change from potential energy to kinetic energy. How do you know? (Lightning can destroy a tree or explode an oil storage tank. *It does work.*) Actually, the electrons move; they are given tremendous kinetic energy.

Why does a spark jump between a charged object and metal objects? Place the diagram of an atom of copper on the board, indicating only the outer of the 29 electrons. How many electrons can have up to eight electrons except for hydrogen and helium, all atoms can have up to eight electrons on the outside. All metals have fewer than four electrons. Somehow, with their fewer outer electrons, metals seem able to attract an electron and the electrical charge is passed from atom to atom; that is, metals permit electrons to flow. Pupils who live in an area where lightning rods are used may wish to explain how they conduct electrons harmlessly.

Investigating the change of electric energy to light energy. Can you make light by using your muscles? Accept hypotheses without comment, and then display the materials in the investigation on text page 237. Let interested volunteers have an opportunity to generate an electric current. Conclude the lesson by asking pupils to be prepared, the next day, with hypotheses as to how the muscular force they put into turning the crank was converted into light.

Extending the Concept

Detecting a static charge. A homemade electroscope may be easily made from simple materials. Run a copper wire through a cork or rubber stopper that tightly fits a jar. Make an L-shaped bend in the lower end of the wire, hang a strip of foil over the L, and stopper the jar. Rub a glass rod with silk or a hard rubber rod with a piece of fur or woolen cloth. Touch the rod to the copper wire. The leaves fly apart because like charges repel, and like charges have been transferred to the leaves from the rubbed rod. Are the charges positive or negative? An interested student should consult a junior high school science or a high school physics book for the answer. To remove the charge, touch the wire with the fin-

Static electricity is stored energy; current electricity is kinetic energy. Metals are good conductors.



Electric energy can be changed into other kinds of energy.

Equipment and Materials

See text page 237; also the Teacher's Manual for Classroom Laboratory 6.

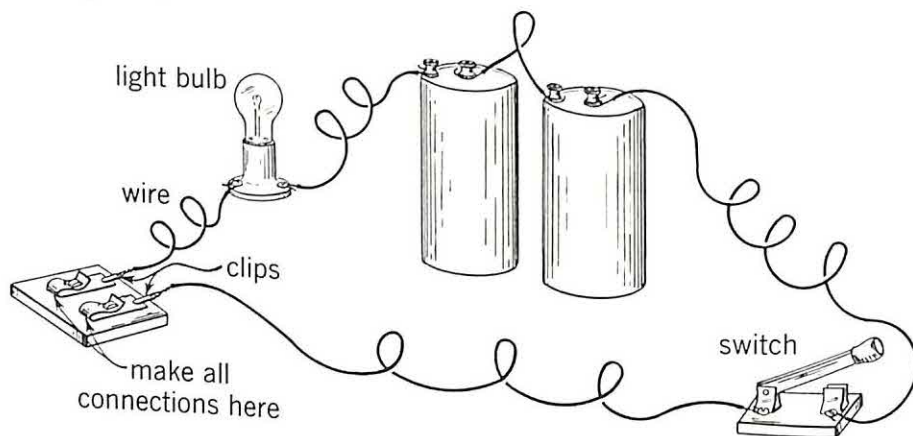
Equipment and Materials

- ... jar
- ... tight-fitting stopper
- ... copper wire
- ... strip of aluminum foil

Equipment and Materials
See figure.

gers. Try rubbing other kinds of substances with other materials. A discussion of electron transfer and a list of activities are on pages 357–61 of *A Sourcebook for Elementary Science*.

Testing conductors. Pupils interested in testing conductivity of different substances may make the device shown in the diagram below. Different substances placed across the switch clips will indicate whether they conduct much electricity by lighting the lamp. Conductivity of liquids can be tested by using a hollow tube that can be plugged with stoppers into which a copper wire has been inserted. Will distilled water conduct electricity? What happens when salt is added? (Salts are a combination of a metal and a nonmetal. Recall the investigation into copper plating on text page 51.)



(Text pages 236 and 238)

Reviewing the Concept

Before You Go On. A. 1. b 2. b 3. a 4. a 5. a

Using What You Know. The pithballs are repelled when the charges are like; attracted when they are unlike.

(Text pages 238–47)

SUBCONCEPT

The energy gotten out of moving electrons is never greater than the energy put into making electrons move through a circuit.

Equipment and Materials

- ... generator from investigation on text page 237
- ... short length of tubing
- ... glass end of medicine dropper

Section 2: GENERATING AN ELECTRIC CURRENT

The pupils, through investigations, begin to appreciate that work (energy) must be put in to make electrons move through a distance (work got out), and that this energy of moving electrons can be transferred as a force and multiplied to do many forms of useful work.

Introducing the Concept

Start by calling for hypotheses on the nature of the generation of electric current (prior investigation, text page 237). If you think of the generator as a machine, what work was put in? (Force of muscles exerted through a distance in turning the crank.) Was the effort force multiplied? (Yes, by the wheel-and-axle effect.) What work was got out? If

you have a class in which some pupils are more perceptive than others, you may get several answers: electrons moved through a distance; heat, or both heat and light. In clarification, you might do several things. First, ask how far the electrons moved. They didn't stop at the light bulb, because disconnecting the wire beyond the light would stop the glow. Examine the wire going to the light bulb and the wire in the light bulb. Which is smaller around? As a model, you may have pupils blow through a short length of glass or plastic tubing and the wide end of a medicine dropper tube (be sure they're sterile). Which offers the greater resistance? In their work with machines and engines in the preceding units, pupils can recall that energy used to overcome resistance was changed to heat energy. If something gets hot enough, it gives off light energy. In this instance, the work done by the electrons in overcoming resistance in the light bulb wire is the useful work; light is wanted. Can a magnet do work? (Of course.) Why do you suppose there was a magnet in the generator? Do you suppose it helped move electrons? Now pupils are ready for the investigation on text page 239.

How can we make electrons move? How can we get more electric current?

Developing the Concept

Generating an electric current with a magnet. Both of the investigations on text pages 239 and 241 may be carried on simultaneously by different groups of pupils, the results reported and compared, and the text read up to "Producing Powerful Electric Currents." A galvanometer is a sensitive instrument. Caution care in its handling; it is capable of measuring small amounts of electric current and should never be connected except as you direct.

Pupils may benefit from a comparison with machines in discussing the three ways in which a flow of electrons can be increased. Since electrons are a form of matter (they have weight—or mass, see page T-114), an increase in flow is equivalent to an increase in the load lifted. More work can be done in the same time by a machine if we can increase the speed, use a greater force directly, or multiply a force. In the two investigations, which part has a force that is multiplied? (The magnet.) How is its force multiplied? How do we know? What machine did we discover (Unit Four) that increased speed? (Wheel and axle.) How do you think a wheel and axle might be substituted for muscles to increase speed? Pupils will probably have little difficulty in inferring that falling water, steam, or another form of energy may be made to turn a bladed wheel, or turbine, to increase the speed, thus giving a greater force that will give a faster push to electrons.

NOTE. Since this section is very long, this may be a good place to conclude the day's work. It will also give more time to investigate the electromagnet, in review of earlier work in science or for those pupils who have no understanding of the concept—or at best a hazy one.

Processes emphasized

Investigation (with design of experiment)
Observation
Analysis of devices
Hypothesizing
Theorizing
Prediction
Measurement
Reporting

A magnet moving in a coil of wire induces a flow of electrons in the wire; this flow of electrons can be increased.

Equipment and Materials

See text pages 239 and 241; also the Teacher's Manual for Classroom Laboratory 6.

A wire through which electrons are flowing has a magnetic field.

Equipment and Materials

- ... bar magnet
- ... iron filings

A stronger magnet may be made by converting electric energy into a magnetic force.

Equipment and Materials

- ... several feet of bell wire
- ... dry cell
- ... compass
- ... small iron nails (brads)
- ... iron spike

Magnetism and mechanical energy together provide a strong and steady flow of electrons; this flow of electrons can be converted into a steady force to do work.

A *stronger magnet*. Actually, the secret of producing a strong and steady current of electricity was the result of a chance discovery. Until then an electric current was more or less an interesting and puzzling phenomenon. In 1819 a Danish science teacher, Hans Christian Oersted, was demonstrating a battery. A wire in his electric circuit was lying over a compass on his demonstration table. As he connected one terminal of the battery, he noticed that the compass needle moved. "Chance favors the mind prepared." Every time he connected or disconnected the wire, the compass needle moved. There must be a magnetic field in the wire, Oersted reasoned.

Magnetic fields can easily be shown. Follow the directions on text page 243, and note the pattern of iron filings. Now run a length of copper wire through a piece of cardboard, support the wire vertically so that it is taut, and connect the ends to a battery of two dry cells. Support the cardboard horizontally and sprinkle filings near the wire and tap the card. The filings arrange themselves into a pattern that indicates a magnetic field. Disconnect the circuit, and tap the card. The field collapses. Magnetism can be made from electricity.

Making a stronger magnet. Pupils may work in groups with the materials suggested. They may wind ten turns of wire around a pencil to form a coil, connect the ends of the wire to the terminals of a dry cell, and hold the end of the coil near a compass. What happens? The needle is deflected. How many brads will the coil pick up? Insert the iron spike and count the number of brads attracted to the end of the spike. (The magnetic field of the wire appears to be concentrated in the spike.) Double the number of turns around the spike. How many brads can now be picked up? Pupils easily infer that the force of the magnetic field around a wire can be increased by more turns and by an iron core. Will increasing the number of dry cells also increase the magnetic force? Let the pupils try it, if they do not recall that it does from earlier work in science.

Electricity from magnetism. In the investigations on text pages 239 and 241, the pupils caused a flow of electrons through a wire by moving a magnet within a coil or moving the wire around a magnet. Michael Faraday was responsible for the discovery that motion of a wire through a magnetic field produces a flow of electrons in the wire. His idea was the reverse of Oersted's. The historical sequence has been reversed in the text to show that the flow of electrons can be increased by multiplying—increasing the magnetic force. Pupils, if they have not finished reading the section should do so now.

Relating the concepts. Many concepts have been developed in this section. It is well to pull them together and perhaps tie down some loose ends. You will probably wish to devise questions on the basis of the following information in order to test understanding. As the pupils pulled and pushed the magnet in and out of the coil in the investigations on text pages 239 and 241, they may have noted that the needle of the galvanometer moved first one way and then the other. The current *alternated*,

but the energy put in did work; the electrons moved. When a wire moves at right angles to a magnetic field, the "rubbing" of the wire against the field sets electrons moving along the wire. The motion of the wire produces motion of electrons. Matter (electrons) in motion has kinetic energy.

Electrons cannot move unless some force makes them move. This means a source of energy, such as muscles, water, steam, or another source. Hitch these sources of energy to a machine to multiply force or increase speed. Find a way to cut magnetic lines of force so that electrons flow. The force of moving electrons can be increased by increasing the turns of wire in an electromagnet (giving it more lines of force), and by increasing the number of turns of wire in the coil (more wires to move across, or cut, lines of force). From what pupils now know of changes from one form of energy to another, they should conclude that the energy got out of producing electricity can never be more than the energy put in.

Extending the Concept

Report. Many great scientists and inventors are connected with the development of electric energy. Interested students may wish to look up one of the following and report on his work: Luigi Galvani, Alessandro Volta (electricity from chemical cells), Hans Christian Oersted, Michael Faraday, James Watt, André Ampère, Thomas A. Edison. All but two of these have had electrical devices or units of electrical measurement named after them. What are they and what do they do or measure?

How does a chemical cell make electrons move through wires? Junior high school texts in science usually discuss the dry cell and produce diagrams. Pupils may be encouraged to find out all they can about dry cells and report their findings. Are they really dry? How long do they last? How can you ruin a dry cell in a short time?

Reading a meter. Less able pupils may investigate how to read a meter and report, with their parents' permission, on the cost of electricity during the month. How much is used? What does the term kilowatt-hour (kwh) mean? What kinds of appliances are used each day and for how long? Could many of these jobs be done in another way? If so, how much longer would it take? That is, how does electricity multiply the forces we have to do work?

Other extensions. For some pupils, the study of electricity is difficult; for others, easy and fascinating. A number of additional and graded investigations into magnetism and electricity are to be found in *Classroom Laboratory 6* and *Invitations to Investigation* (see page F-18). Films and filmstrips are also useful in developing concepts in electricity. (See pages T-111-12 for a selection.)

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. d

(Text pages 246-47)

(Text pages 247-56)

SUBCONCEPT

The energy of moving electrons can be used to do work.

Processes emphasized

Observation
Analysis of devices
Building working models
Library research
Hypothesizing
Theorizing
Prediction
Reporting

Electric energy can be converted to sound energy by a mechanical device.

Using What You Know. 1. A source of energy. 2. A magnetic field around the magnet; the filings should be arranged in an elliptical pattern, running from one end of the magnet to the other. 3. Potential energy is stored energy (due to position, tension, or chemical composition; also other means of storage); kinetic energy is energy of motion.

Section 3: ELECTRIC BELLS AND ELECTRIC MOTORS

Having learned that energy must be used to make electrons move, pupils discover that this energy can be harnessed to machines to do work. The kinetic energy of moving electrons is changed to mechanical energy. Machines can multiply the force.

NOTE. Since this section calls for the building of two operating models, you may wish to extend it over four or five days to give all pupils experience with both models—one day for the building of each model and one day for reports and discussion. If two separate groups work on the models, the section may be covered in a shorter time.

Introducing the Concept

Sometimes a good way to generate interest is by telling an anecdote or two. Where did the word *electricity* come from? Pupils may think it comes from the outer particle rubbed off atoms. But it has a far more ancient history. About 2,500 years ago a Greek philosopher named Thales noticed that if amber was rubbed rapidly with a cloth it picked up small particles. The Greek word for *amber* was *elektron*, but it was not until nearly the end of the reign of Queen Elizabeth I that anyone was much interested in its effect. In 1600 William Gilbert, an eminent scientist, wrote *On the Magnet*, a book in which he described a number of experiments he had made. He coined the word "electrics" for the objects that acted as amber did in attracting other objects. And the name stuck. Of course, it was static electricity. Incidentally, a generator, which uses a magnet, is often called a magneto.

What might be a better name for electricity? Recall that man invented all sorts of machines to multiply force, to change its direction, and to transport himself. Wouldn't it be wonderful if he could bring the energy to himself, without having to move machines and materials to the source of energy! What word do we use for "sending" written words over wires? Sounds over wires? Pictures through space? What would you think of the terms *teleforce* or *telepower* to describe electricity?

How can we use electric energy to do work at a distance?

Developing the Concept

The electric bell. After pupils have read "The Purpose of Switches," investigate the similarities between an electric bell and an electric motor, as suggested on text page 249. Encourage hypotheses as to how an

Equipment and Materials

See text page 254; also the Teacher's Manual for *Classroom Laboratory 6*.

may be roughened and made less sharp by light filing. In an actual motor, the rotating part (armature) is an electromagnet in which a special device, called a *commutator*, reverses the direction in which the current flows through the armature for every half turn it makes. This has the effect of changing the poles of the electromagnet so that it is alternately attracted and repelled by the poles of the magnet within which it rotates. There may be four, eight, or more coils on one armature, thus making as many electromagnets as there are coils.

Pupils should note the difference between a generator and a motor. They should trace the electric current flow through their model and compare with the generator on text page 237. The generator builds up electric potential, which becomes kinetic energy as electrons flow through a complete circuit. A motor multiplies the force given by moving electrons and transfers it to a machine, usually a wheel and axle, which may further multiply force or increase speed.

Extending the Concept

How does a thermostat work? This device operates like an electric bell, making or breaking an electric circuit by means of contact points. Interested pupils should investigate the spring action of the bimetallic strip as the room gets warmer or cooler.

What do motors do? How many devices can you find that use electric motors? A display of illustrations of motors of all sizes with some of the kinds of work they do would make an interesting bulletin-board display. What does horsepower mean in a motor? How is it figured? Find out how James Watt figured it.

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. a

Using What You Know. A. (*Electric bell*) 1. Contact point (breaks the circuit). 2. Clapper (moves back and forth to sound the gong). 3. Electromagnet (attracts the metal clapper when current flows through circuit, releases clapper when circuit is broken). 4. Gong (sets molecules of air in motion, we hear sound). (*Electric motor*) 5. Electromagnet (attracts armature and keeps it spinning when circuit is completed by contact of armature and brush). 6. Armature (turns a wheel-and-axle type of machine). 7. Brush (completes the circuit when armature touches it). 8. Switch (device to connect motor to source of electricity; opened or closed manually). B. 1. and 2. In the generator a magnet is turned within a coil (or a coil within a magnet) to produce electric energy. In a motor an electromagnet (armature) is turned within a magnetic field to convert electric energy into mechanical energy. In other words, a generator converts mechanical energy into electric energy; a motor converts electric energy into mechanical energy.

(Text page 256)

Section 4: ELECTRIC SIGNALS

Pupils, through investigations and model building, see how sound (the motion of molecules in air) can be converted into electric signals by means of electromagnets, transported over wires, and reconverted into sound.

Introducing the Concept

The introductory paragraphs raise questions which may be used to start thinking about the many uses of electricity as a means of communication. Or you may start first with other questions such as these: If you had no telephone, how would you send a signal to a friend that you wanted him to come over and play tennis? What signaling devices have people used in the past? Pupils may recall smoke signals, blinking lights, beating of drums, flashing mirrors, and semaphores. What did these all rely on? (Sight or sound.) There would have to be a way to get the receiver's attention, and some code to carry the message, would there not? You have already built a model of one kind of electric signal. What was it? (The electric bell.) How would you go about using the bell to carry a message?

What part in the electric bell is in every telegraph or telephone set? How do the telegraph and telephone work? Does the sound of your voice travel over the telephone?

Developing the Concept

A model telegraph. After reading and general commentary on "Messages by Code," pupils should build and operate the model telegraph (text page 259). Two sets are needed for communication at a distance (telecommunication). For classroom use, a light bulb may be substituted for the sounder, and the message read by decoding the signals from the flashing light. Encouraging learning of the International Morse Code may produce a foundation for a later hobby as a radio "ham."

As a result of this model-building activity, pupils should be aware that the essential part is the electromagnet, which is sensitive to every alteration in the timing of the pressure on the key. The sounder bounces up and down instantaneously with each up-and-down motion of the finger on the key. The instant the switch (key) closes the circuit, electrons flow; the instant it breaks the circuit, electrons stop flowing. The switch converts the force of the finger into electric energy. This is changed to a magnetic force that pulls down the sounder. By what kind of energy does the sounder convey the message? (Sound, movement of molecules.)

What is sound? Pupils may need no review of sound as vibration, a form of mechanical energy imparted to molecules of matter. Unit One of *Concepts in Science 5* developed the concepts of sound as energy traveling as a wave. You may wish to add a copy to the science reading table in the classroom. If there seems to be need for a brief review, stretch a

(Text pages 257-67)

SUBCONCEPT

Sound waves may be converted into varying strengths of electric current, transferred through a conductor, and reconverted into sound waves.

Processes emphasized

Observation
Analysis of devices
Development of working models
Hypothesizing
Theorizing
Prediction
Library research
Consulting

Opening and closing a switch in an electric circuit can be used to transmit signals.

Equipment and Materials

See text page 259; also the Teacher's Manual for Classroom Laboratory 6.

Sound is the vibration of molecules in a wavelike pattern.

Equipment and Materials

... embroidery hoop
... tissue paper
... fine sand
... Slinky

Sound waves can be converted into electrical energy, transmitted over a circuit, and reconverted to sound waves.

Equipment and Materials

See text pages 263 and 265; also the Teacher's Manual for Classroom Laboratory 6.

sheet of tissue paper taut over an embroidery hoop. Pulsations of the paper will be seen if you hold it close to your mouth and speak against it. Or sprinkle fine sand over the paper and hold it above a vibrating object—an alarm clock for example. The sand grains will “dance” up and down. Perhaps all that will be necessary is for the pupils to say “hello” against their hand held an inch or two from their mouths. The push of air molecules will be felt.

Where else have we used moving molecules to do work? (Heat engines.) Is heat the same as sound? (No. All molecules are in motion and possess kinetic energy; that is, heat.) The mechanical energy in a vibrating object makes the molecules move back and forth. They transmit the energy to any other object they strike against. How sound waves travel can be modeled by hanging up a loose-coil type of spring, such as a Slinky. Hitting one end will show a ripple of motion, an alternate squeezing and lengthening, which resembles the motion of sound waves. You may wish to end the day's lesson at this point with “Tomorrow we'll build a telephone. What do you think we'll need?”

A model telephone. After pupils have read through “What Happens to Your Voice,” they are ready to start building the model telephone (text page 263). They will learn more from this activity than from any amount of general discussion. You may wish, when the telephone is set up, to demonstrate that a flick of the fingernail against the transmitter will be heard in the receiver; especially do this if pupils are skeptical that sound is a form of mechanical energy. Pupils should trace the energy conversions from mouth to ear through the entire hookup. Which parts change energy from one form to another? (The electromagnets.) Which parts merely transmit a force exerted by a form of energy? (The disks, wires, carbon granules, etc.) If a modern telephone set is available, the pupils may reinforce the concepts by examining it as suggested on text page 265.

Extending the Concept

A visit to a telephone exchange. If you can arrange an appointment with the local telephone company, the pupils will come away with a heightened sense of appreciation for the technological complexities of modern telephone communication. Perhaps the operation of the teletype and the dial telephone can be simply explained and shown by the company's representative.

Biographical reports. Encourage the pupils to find out all they can about Samuel F. B. Morse, inventor of the telegraph, and Alexander Graham Bell, inventor of the telephone. What obstacles did each have to overcome? What changes did these inventions bring about within 20 or 25 years?

One day without electricity. The importance of this form of energy can be dramatized by pupils who like to write. They can invent an imaginary story or write a report of an actual event, resulting from flood, hurricane, or a break in the power line.

Reviewing the Concept

Before You Go On. A. 1. 1. Key (transmits electric signal). 2. Dry cells (source of electric energy); 3. wire (one part of the complete electric circuit; electrons flow through it); 4. electromagnet (when circuit is closed, it attracts sounder); 5. sounder bar (produces an audible clicking noise as the circuit is closed). 2. 6. Transmitter (collects sound waves); 7. metal disk, or diaphragm (vibrates with sound waves and transmits energy to carbon granules); 8. carbon granules (change vibrations into a pattern of electric impulses); 9. receiver (transmits sound waves); 10. disk, or diaphragm, (vibrates and transmits sound waves according to original sound pattern); 11. electromagnet (attracts disk in accordance with varying flow of electricity through circuit).

Using What You Know. 1. Both have devices for converting one form of energy to another. 2. The transmitter's carbon grains change sound into electric energy; the receiver's electromagnet changes electric energy into sound.

Section 5: RELAYS WITHOUT WIRES

Pupils complete their investigation of energy conversion and transmission with an examination of the concepts (ideas) and inventions (tools) that have made communication through space possible.

Introducing the Concept

In how many ways can we transmit signals without wires? To this question, your pupils will immediately answer with radio and television. What other ways are there—what kinds of devices? Write the word **ELECTRONICS** on the chalkboard. This term should suggest tubes and transistors and a host of appliances that transmit signals—from opening the garage door from a distance to signals from a spacecraft speeding towards Mars. Free discussion of how these devices work should be allowed to run without corrective comment.

You may perhaps also wish to explore the question: Why were there no radio stations until 1920? The key questions, however, are:

What is an electromagnetic wave? How fast does it travel? How can it carry a signal?

Developing the Concept

Investigating magnetic force from a wire. Suppose you wanted to send a message to an astronaut or to a place where telephone wires could not be strung. How could you devise a way to do it? Recall that once simple machines had been invented to multiply the force of muscles, man looked around for more energy. Machines were linked with steam and fuels. Was there a source of energy that could be linked with electricity? The perceptive pupils may recall that magnets can do work and that a wire moving through a magnetic field produces electricity. Or you may

(Text page 267)

(Text pages 268–78)

SUBCONCEPT

Electric energy can be changed to electromagnetic waves that can carry signals through space at the speed of light.

Processes emphasized

Observation
Analysis of devices
Reporting
Computation
Measurement
Hypothesizing
Theorizing
Prediction

Whenever electrons flow through a wire, they set up a magnetic field around the wire.

Equipment and Materials

See text page 269; also the Teacher's Manual for Classroom Laboratory 6.

energy as the electrons strike them. The pattern of light is reproduced exactly as it was picked up by the television camera—the same number of lines, the same number of dots, and the same number of pictures per second. To diagram energy conversions in television broadcasting, substitute light for sound. Again, the concepts can be understood, but the technology is beyond pupils at this level.

Space communication. In these days of unmanned as well as manned spacecraft, it is hardly necessary to do much more than let the pupils have free rein in reporting information they have gleaned from newspapers and television broadcasts. You may, however, wish to ask pupils to relate what they report to the types of energy conversions and transfers they have been studying.

Extending the Concept

Reports. Perhaps only the more able pupils in the class can read and report on such topics as kinds of tubes in radio or television sets, AM and FM, or assignment of channels to radio and television; but most pupils will enjoy gathering illustrations of various communication satellites. A junior high school textbook, such as *Exploring the Sciences* by Paul Brandwein and others, will be helpful. The National Aeronautics and Space Administration (NASA), Federal Office Building, No. 6, 400 Maryland Ave., S.W., Washington, D.C. 20025, is an excellent source of information and illustrations for the different series of satellites (Ranger, Explorer, Echo, etc.).

Examining a vacuum tube. Enlist class assistance in gathering a few discarded electric light bulbs, radio and TV tubes (*never* a picture tube). Wrap in an old piece of cloth or toweling and carefully break the glass. What differences are noted in the filaments? The square of metal in the electronic tube is the plate. Between the plate and the filament is a screen called the grid. A tiny change of electricity on the grid makes a big difference in the strength of the current passing from the filament to the plate. This means that the radio tube can amplify a weak signal. This was Lee De Forest's invention in 1906 that led to the development of radio and television. Interested pupils may find out what they can about De Forest and report on his work to the extent they are able to comprehend the working of a vacuum tube. Others may wish to report on Guglielmo Marconi's work with wireless transmission.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. a 4. b

Using What You Know. 1. a. Both convert sound waves into electric energy and reconvert electric energy into sound waves. b. The telephone has three energy conversions—sound to electric energy to sound. The radio has five energy conversions—sound to electric energy to electromagnetic waves to electric energy to sound. 2. Radio telephone transmits electromagnetic waves through space; ordinary phone transmits electric energy over wires.

Electromagnetic waves can activate devices in space to gather light and sound and transmit their signals to earth.

(Text page 278)

Electron tubes are used to convert the energy from one form to another in the radio telephone; the ordinary telephone uses carbon granules and an electromagnet.

Section 6: THE MAIN CONCEPT: CHANGING AND TRANSFERRING ENERGY

As pupils re-examine sources of electric energy, they comprehend more fully that the first source of energy is the sun, that energy is constantly being changed from one form to another, and that there is no loss or gain of energy during the process.

CONCEPT SUMMARY

How does the sun run your TV set? Place a circle on the right-hand side of the chalkboard and label it SUN, as you ask the question. In what forms of matter does the sun store energy on earth? If necessary, review that stored energy is potential energy because of its position or chemical composition. Pupils should be able to cite water, food, and fuel. How is water given potential energy? (The radiant energy of the sun is converted to heat energy [kinetic energy of vibrating molecules], and water evaporates. The lighter, moisture laden air is pushed upward by the downward pressure of heavier, colder air. The water vapor condenses, falls as rain, and is gathered in lakes or rivers or behind dams. It obtains potential energy of position.) How is the potential energy of water converted to electricity? (In two ways: by turning a machine directly; by a physical change to steam which turns a machine.) What changes take place as electric energy is transferred to light energy in the TV set? (See pages T-127-28.)

Bring out that each form of energy develops a force that does work. Anything that moves has energy and can do work. For example, the force of moving molecules of water is transferred by machines to give atoms potential energy (a difference in charge of electrons). Various devices transfer the force of moving electrons to set electromagnetic waves in motion.

NOTE. As pupils develop the concepts of energy changes and transfers, you may wish to chart them on the board, leading out from the circle labeled SUN (next page), leaving the atom out for the moment. Matter-energy relationships are the subject of the next unit.

After the above example, it is well to have the pupils read the section, if they have not already done so. Encourage them to trace the transfer of energy stored in fuels and food by the process of photosynthesis. You may find it necessary to ask a few guide questions, such as the following, to keep the pupils on the track. It is beneficial to their thinking, however, to let them attempt to formulate the concepts themselves. What form of potential energy do foods and fuels have? (Chemical.) How is

(Text pages 279-83)

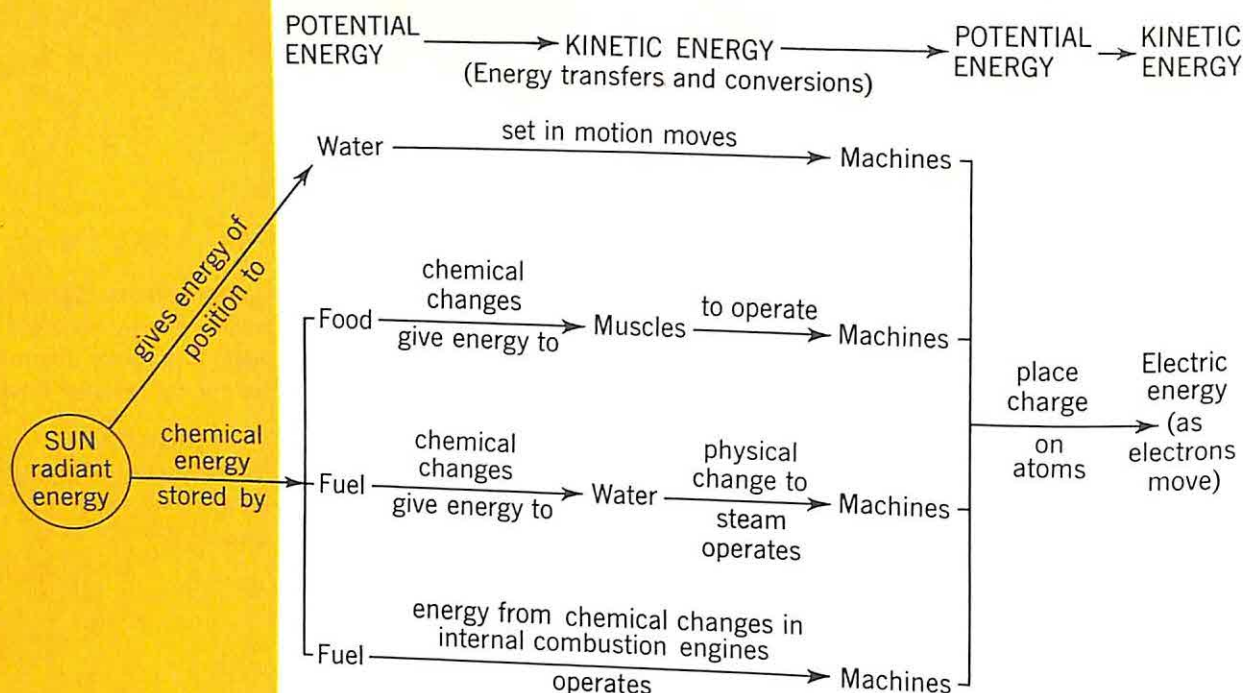
CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

UNIT CONCEPT

The amount of energy gotten out of a machine does not exceed the energy put into it.

In how many ways can we obtain electric energy by changing or transferring other forms?



the stored chemical energy changed to kinetic energy? (By a chemical change; oxidation and combustion impart kinetic energy to the molecules; that is, heat energy.) How does the heat energy show that it exerts a force? (By moving muscles; by turning wheels or activating other machines.) Are muscles and machines a form of energy? (No. They are merely devices for transferring energy.) What do machines do? (They multiply a force, change the direction of a force, or increase the distance a force travels, as developed in Unit Four.)

How is the force generated by the energy of burning fuels multiplied in the steam engine? (By a physical change of water to steam.) How is this force transferred? (By a piston and machines that transfer the force to move electrons; that is, to generate electrical energy.)

From what bit of matter can we get electric energy? (The atom.) How? (By giving it an electric charge.) Is this electric charge potential energy or kinetic energy? (Potential; the electric charge is greater than on neutral or oppositely charged atoms.) How do we change this potential energy into kinetic energy? (By getting the charges—electrons—to move.) How? (By connecting them into a circuit. As long as there are more electrons at one end of the circuit than at the other, electrons flow.) How can we give substances a charge? (By moving an object against a resistance as by rubbing—friction—or by moving a wire or coil through a magnetic field.)

If a pupil does not understand the concept of work, he is likely to go wrong on this question. Turn on a desk lamp and let it burn for a moment or two. What work is being done by the moving electrons? *Both*

Is all the force generated by electricity used to do work?

heat and light are evident, the one by sight and the other by touch. The light bulb is a kind of machine invented to change electric energy into light energy. Work is done when one form of energy is changed to another. Thus, useful work done by the moving electrons is to provide light, but the actual work done includes generating both light and heat. Place your hand on a radio after it has been running for a while, or on the housing of a motor. Heat is felt in each instance. At least two energy conversions are made whenever energy is transferred or changed from one form to another.

FIXING THE MAIN CONCEPT

(Text pages 280-83)

Testing Yourself. 1. Friction of the car against the road and of the gasoline sloshing back and forth in the tank gives the body of the car a charge of electricity. The wire leads the charge into the ground; otherwise the toll collector might get a shock. 2. No. An electromagnet is necessary to pull the clapper and release it as electricity flows through a circuit. 3. No. A disk, or diaphragm, is necessary to transmit the vibration of sound waves to the carbon granules, which convert these vibrations into electric signals. 4. No. An electromagnet is needed to convert electric impulses by attracting a diaphragm in the receiver. 5. No. There is no source of electricity connected to the electromagnets.

Quick Test. 1. a 2. b 3. b 4. a 5. b 6. b 7. a 8. a 9. b 10. b
11. a

On Your Own. 1. The circuit is broken. 2. Close the switch. 3. Position b; the mercury must be in contact with the wires to close the circuit.

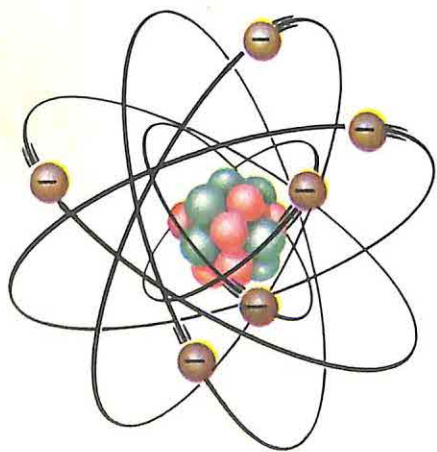
1. "Rubbing" Off Parts of Atoms

Have you ever scuffed across a wool rug and felt a small shock when you touched another person or a piece of metal? If it was dark, you may even have seen a spark. Also, when you combed your hair on the same day you may have heard a crackling sound.

What do these observations—the shock, the spark, the crackling—mean? By doing the investigation on the opposite page, you will add to these observations and be able to make sense of them.

One Explanation

Look around you. *All* the things you see are made of atoms. The atom shown in the diagram is an atom of carbon, greatly enlarged. ■ The real carbon atom is very small; it is so small that it would take millions of carbon atoms to make a piece of carbon big enough for you to see.



In the center of the atom is the **nucleus** (nōō'klē-əs) and revolving around it are **electrons** (i-lek'tronz). Electrons are tiny electrically charged particles. They are *negative* charges of electricity.

The electrons "rub off" onto the plastic rod or the comb. The term "rub off," however, is not accurate. It is better to say that the electrons in certain substances (for example, wool) are easily transferred to other substances such as hard rubber (vulcanite) or plastic. The rubbing helps to transfer the electrons.

Electrons can be transferred from many substances to other substances by rubbing. The plastic rod seems to collect the electrons from the wool.

A negative charge is usually written as *minus* charge or just plain "—". The more electrons the rod collects, the stronger the negative charge becomes. Each electron is really a single unit of negative electric charge.

The rod has a negative charge because it has collected extra electrons. On the other hand, the bits of paper or the stream of water have *not* collected extra electrons. If they had, they would have a negative charge also. Clearly the negative charge on the rod is different from the *neutral* state of the bits of paper or the stream of water. In fact, the paper and water have no charge; that is the meaning of the word "neutral." When there is a difference in charge on two substances, the substances attract

AN INVESTIGATION into a Force of Attraction



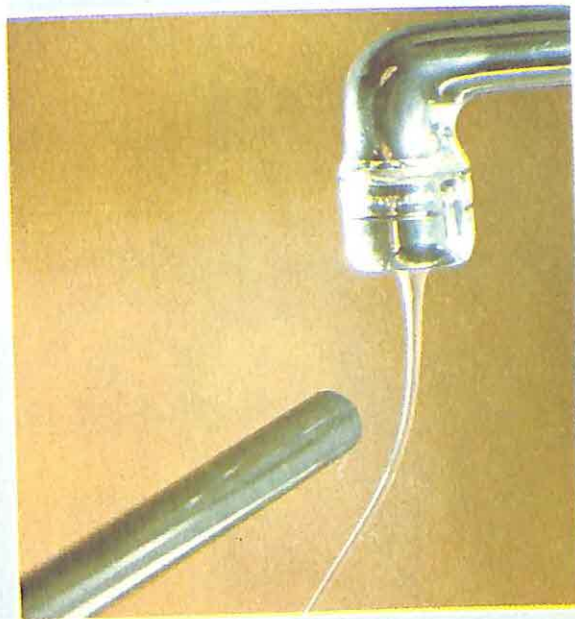
Needed: a plastic, or vulcanite, rod or comb; a piece of wool or fur; a balloon; tissue paper

First, tear up bits of tissue paper. Hold the rubber rod or the comb near them for a moment, then remove it. Were the bits of paper attracted to the rod?

Rub the rod or the comb briskly with a piece of wool or fur. ■ Again bring the rod near the bits of paper. ● Does the rod attract the bits of paper now?

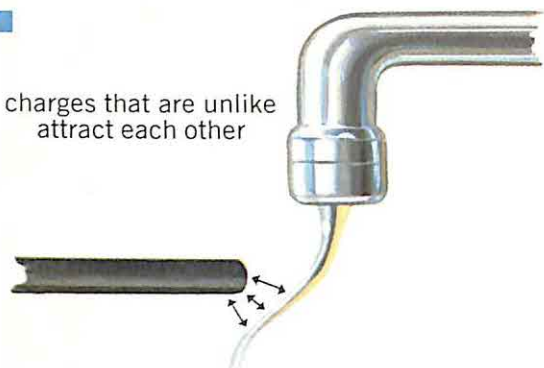
Bring the rod near a stream of water. ▲ Does the stream bend toward the rod?

Now briskly rub the wool or fur against the side of an inflated balloon. Throw the balloon to the ceiling or place it against the wall. Does the balloon stay there?



Additional Investigation: Sometimes, however hard you try, the balloon does not stay on the ceiling or on the wall. What kind of day is best for this investigation?

charges that are unlike
attract each other



each other; thus the paper and the water are attracted to the rod. ■

The opposite of a “negative” charge is a *positive* or *plus* (“+”) charge. A substance develops a positive (+) charge when it loses electrons. The piece of wool, for example, developed a positive charge when it lost some electrons to the rod.

When a substance with a positive (“+”) charge is brought near a substance with a negative (—) charge, the force of attraction is strong.

Again, rub the piece of wool against the rod, and then pass the rod back and forth about $\frac{1}{4}$ -inch above the part of the cloth you just rubbed. ● Do you find that the small fibers of wool are attracted to the rod? They are attracted because the charges are different. The part of the wool cloth that was rubbed is positive (+), the rod is negative (—).

The bits of paper are neutral; they have no charge (neither negative, nor positive), but they are attracted to the negative rod because there is a charge difference between the paper and the rod.

Would the pieces of paper also be attracted to the positively charged part of the wool cloth? Test your answer.

Static and Current Electricity

Electricity that is not moving is called **static electricity**. When the

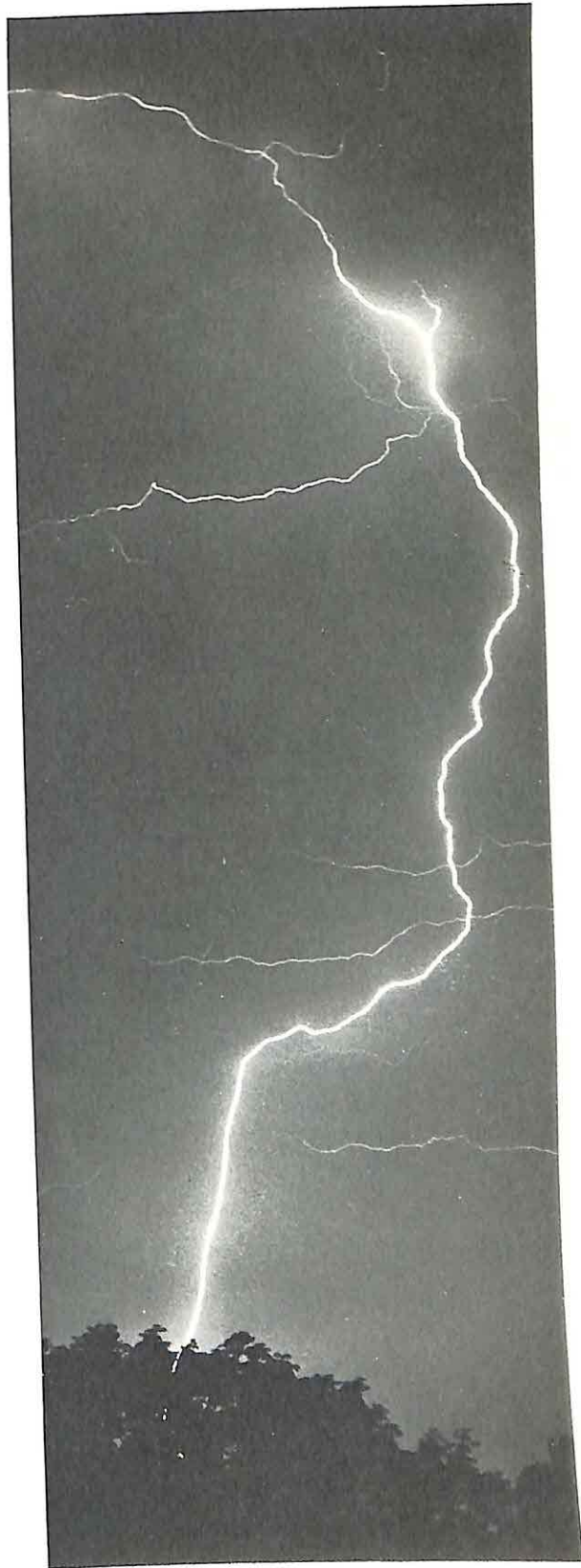


electrons collected on the rod, the rod had a charge of static (not moving) electricity. A charge of static electricity can be removed, or discharged, by bringing the substance near a good **conductor** of electricity. A conductor is any substance, such as metal, through which electrons can flow easily.

Recall your experience when you walked on a wool carpet. You were charged with electrons as you scuffed across the wool carpet, but you discharged the electrons when you put your finger close to something made of metal.

In a thunderstorm, great amounts of static electricity are discharged. Clouds moving in the atmosphere can collect a charge of electrons. When the charge becomes great enough, lightning flashes through the sky. Lightning is a discharge of static electricity. The electrons may be attracted to a metal lightning rod or even to a tree.▲ Even though a tree will not conduct small charges of electrons, a flash of lightning is powerful enough to pass through it. Lightning, then, is a huge number of electrons that move fast—suddenly, with a flash of light. The sound of thunder follows.

You can move electrons in another way. Of course you have turned on the electric light, or television, or radio. With a flick of the switch electrons flow along a wire. Electricity moving through a wire is called **current electricity**.



When you flick a switch, you do not use static (nonmoving) electricity, but current (moving) electricity. In other words, a light bulb glows when electrons are moving in a wire (current electricity). See for yourself by doing the investigation on the opposite page.

From Muscular Energy to Electric Energy

There are many forms of energy. When you lit the bulb by means of the hand generator you changed en-

ergy from one form to another. The chemical energy from food in your body was changed to mechanical energy (movement of the arm). The mechanical energy was changed to electric energy and then to light energy.

When you cranked the generator, then, the chemical energy from the food in your body was changed into electric energy, the energy of moving electrons. Now let us search further into the way electrons can be made to move.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

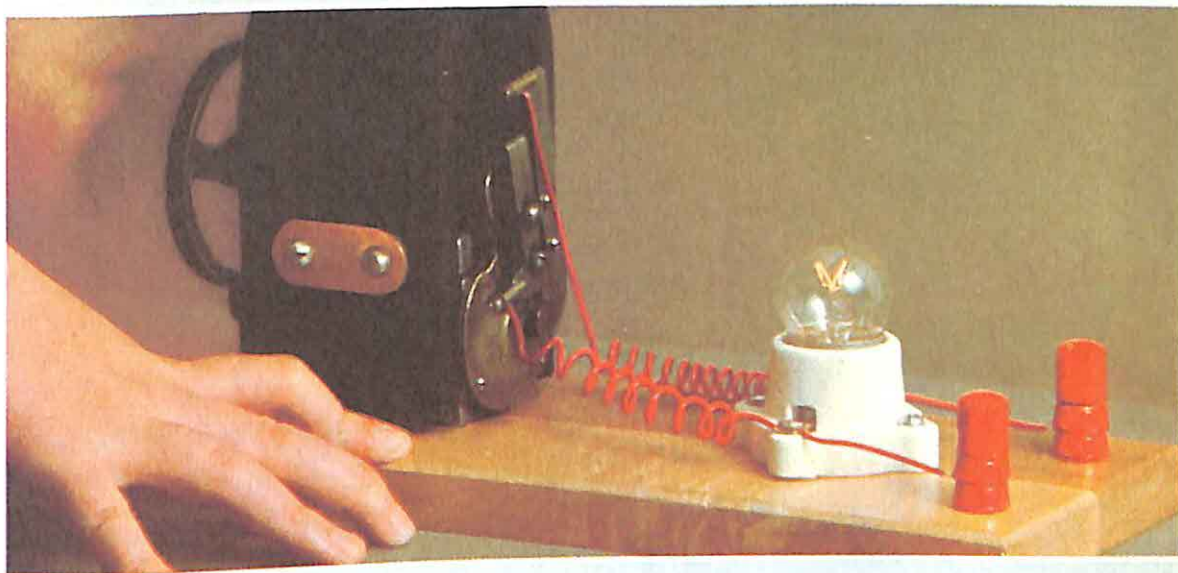
1. All the things around us are made up of
 - a. compounds
 - b. atoms
2. When a plastic rod is rubbed with wool or fur, it collects
 - a. protons
 - b. electrons
3. The sign which would show the charge of an electron is
 - a. “—”
 - b. “+”
4. When there is a difference in charge on two substances, the substances which are differently charged
 - a. attract each other
 - b. repel each other
5. Electricity that is not moving is called
 - a. static electricity
 - b. current electricity

B. Write a paragraph or two on this topic: Two Kinds of Electricity.

USING WHAT YOU KNOW

In the diagrams on page 238, you will find what are called *pith balls* hanging from strings.

AN INVESTIGATION into Lighting a Bulb with an Electric Current



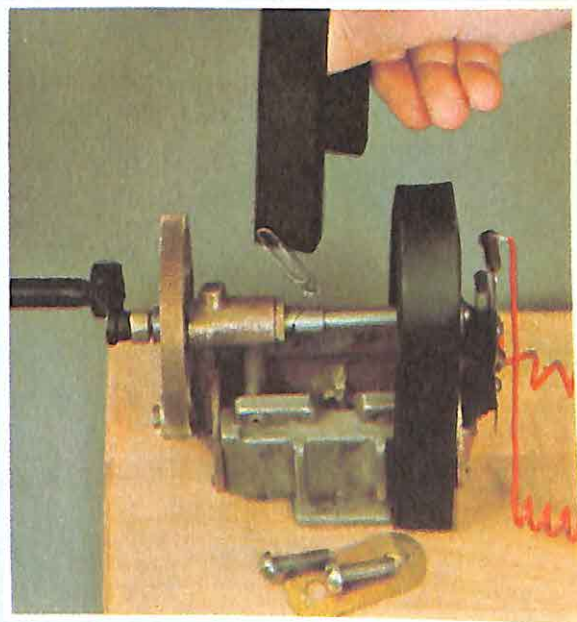
Needed: a small hand generator; a socket, as shown; and a small bulb

If your school has a small hand generator like the one shown, examine it carefully. ■ The purpose of this investigation is to see what it does and how it works.

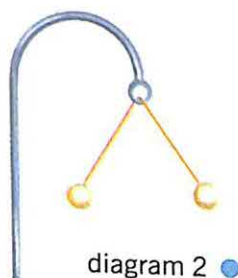
Place a small bulb in the socket of the generator, and turn the crank quickly. ■ Does the bulb light up? It should light up as electrons move through it. You have generated an electric current, or a stream of electrons moving through a wire, to light the bulb.

Current electricity is lighting the bulb. Where did the electric energy to light the bulb come from? What energy changes took place?

Ask your teacher to help you take the generator apart. ● What are the U-shaped pieces of metal, and what are they used for? What turns inside these metal “U’s”?



In diagram 1, the pith balls have been charged with electricity. ■ In diagram 2, the pith balls also have an electric charge. ●



1. Which diagram shows pith balls charged with unlike charges of electricity?
 2. Which diagram shows pith balls charged with like charges of electricity?
- Explain your answer.

2. Generating an Electric Current

When you turned the crank of a generator, you did some work to produce the electric current. Recall from Unit Four the scientist's concept of the word *work*. Whenever an object is moved through a distance, *work* is done. In the hand generator, which object was moved through a distance? The crank moved as you turned it, and the coil inside the magnet moved as well. As it spun around, somehow an electric current was produced.

Let us look further into the way an electric current may be produced by doing the investigation on the opposite page.

Electric Current— An Explanation

What happened when you stopped moving the magnet; in other words, what happened when you stopped doing work? The needle stopped moving as well; there was no flow of electrons.

The chemical energy in your muscle cells is changed into the mechanical energy which moves the magnet. The mechanical energy of the moving magnet was changed to electric energy in the coil. In order to change one form of energy to another, work was done. You worked to move the magnet through the coil. Electric energy in the coil moved the needle. When you stopped, the needle stopped.

AN INVESTIGATION into an Electric Current

Needed: a meter, a **galvanometer** (gal'və-nom'ə-tər), as in the picture; ■ about 50 feet of insulated bell wire; a strong magnet; a cardboard tube

The meter measures the flow of electrons so that each time the needle swings, it is an indication that electrons are flowing.

Did you notice the two knobs on the meter? These are the terminals, the places where the two ends of the wire are attached.

Now make a coil by winding about 75 turns of wire around the cardboard tube. Insert one pole of the magnet into the coil. Pull and push it back and forth inside the tube. ■

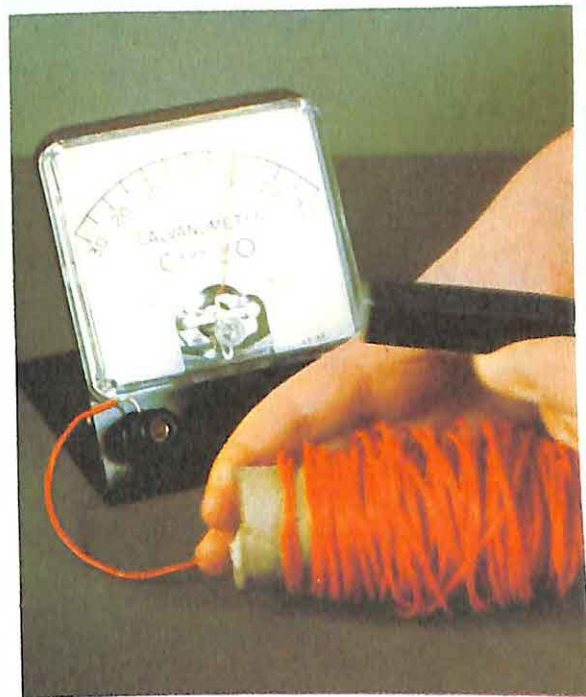
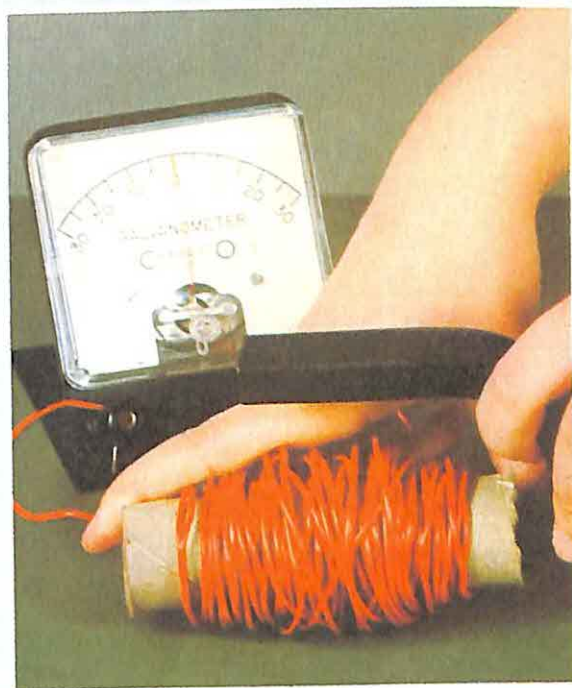
Does the needle move? If so, you have produced an electric current.

What happens when you hold the magnet inside the coil but do not move it back and forth? ●

What must happen if an electric current is to be produced?

Additional Investigation: What happens if the magnet is held still while the coil around the magnet is moved back and forth?

Try to develop a hypothesis of what might happen. Then find out by investigation if your hypothesis correctly explains what happened.



Does a greater amount of work result in a greater flow of electrons? The investigation on the opposite page will help you to answer this question.

The Ideas Behind Electricity

The ideas behind electricity are simple. One way to produce a small electric current (flow of electrons) is to move a magnet in a coil of wire, so that it quickly passes each of the turns in the coil. Can you guess how it is possible to make the flow of electrons great enough to light a factory or a home or to run a machine? The investigation you just completed on the opposite page provides several important clues.

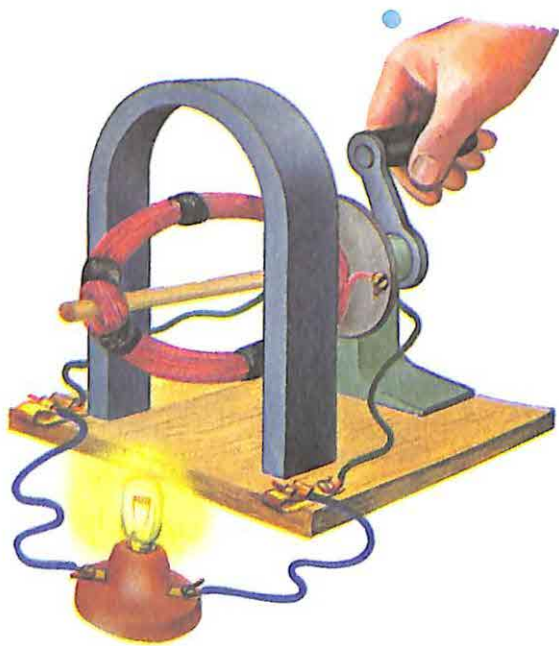
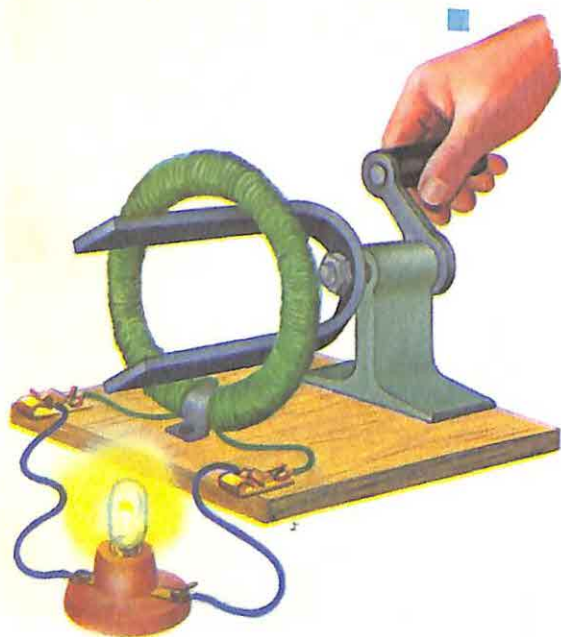
To help you remember, let us review some of these clues. When an electric current is produced by a mag-

net in a coil, the flow of electrons can be increased by:

1. moving the magnet faster;
2. using a stronger magnet;
3. increasing the number of turns of wire on the coil.

You can make a good guess about what is needed in a generator. Recall the way you made electrons flow in the wire (page 237). Then look at the drawing which shows the inside of one kind of small generator. ■ Do you see a magnet? Do you see the coil of wire? *When the magnet is moved inside the turns of wire in a coil, electrons flow.*

In another type of generator (such as the one shown in the investigation on page 237), electrons flow *when the coil of wire turns between the poles of a magnet.* ● With either generator work must be done to light the bulb.



AN INVESTIGATION into the Flow of Electrons

Needed: a homemade coil on a cardboard tube; an electric meter (galvanometer); a strong and a weak magnet

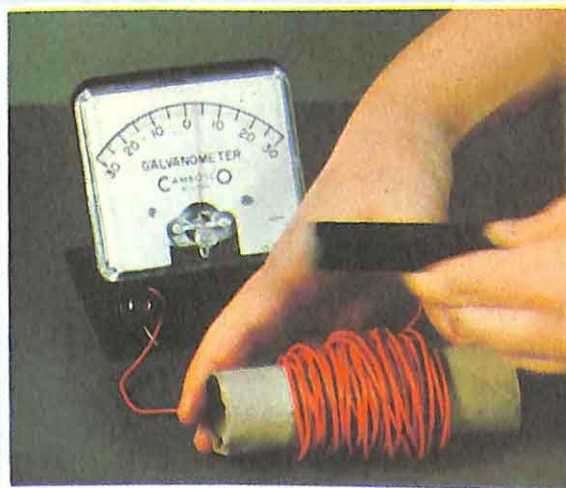
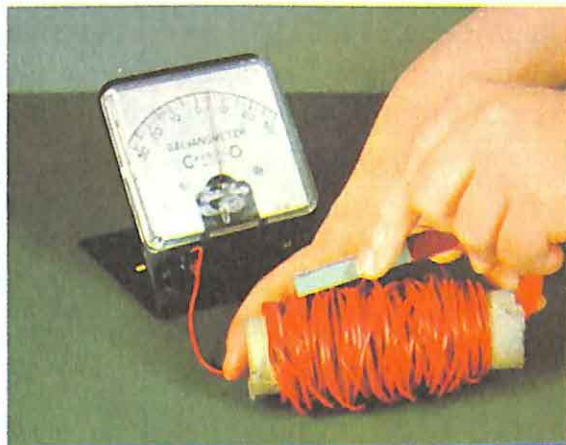
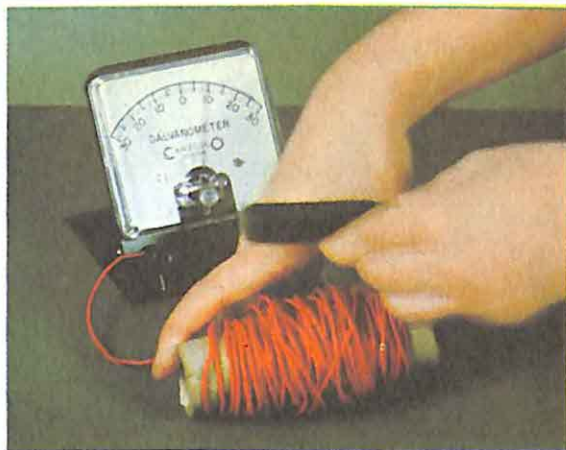
Attach the coil to the meter, as shown in the investigation on page 239. Insert the strong magnet into the coil and move it back and forth very slowly. Record the highest reading.

After you have recorded how much the needle moved, insert the magnet again. This time move it back and forth rapidly. ■ Do you notice a higher reading on the meter? Was a greater flow of electrons produced by moving the magnet faster?

Now insert the pole of a weaker magnet into the coil. Move it back and forth rapidly. ● Which magnet gives a higher reading, the stronger or the weaker magnet? Which produces a greater flow of electrons?

Remember the last reading on the meter when you inserted the strong magnet. Begin to unwind the coil of wire. Take off about half the loops, then cut the wire and attach the smaller coil to the meter as before. Again insert the strong magnet into the coil, and move it back and forth at the same speed as before. ▲

Does the meter read less? Does the number of turns of wire affect the flow of electrons?

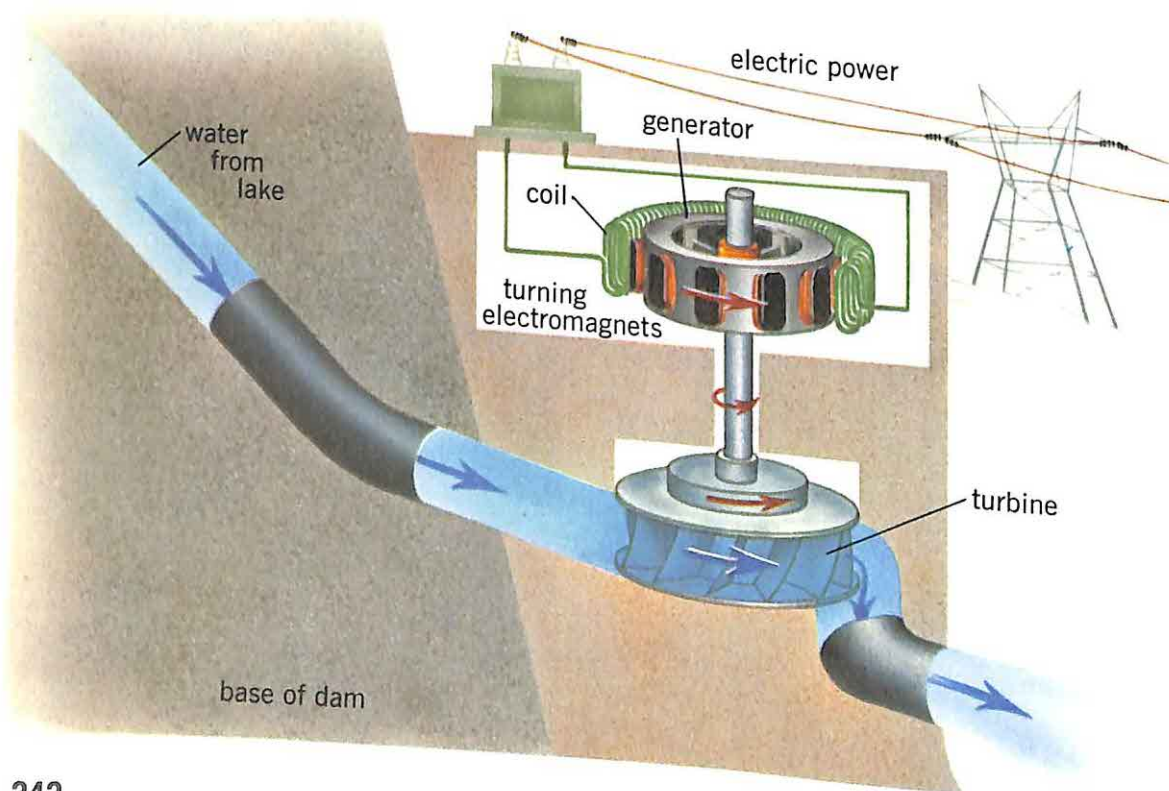


For a small generator, the muscle of your arm does the work to move the magnet or to move the coil. The small hand generator changes the mechanical energy of your muscles into electric energy; yet it can light only one small bulb. At this rate, a large number of people would be required to turn many generators in order to light even one small house. How then are commercial, large-scale generators turned? One way utilizes the energy of water falling through a dam. This energy can be used to turn a turbine, as shown. ■ Then the turbine does the work of turning the magnets or coils of wire. Another method utilizes the force of expanding steam to turn the turbine, which then moves a generator.

The next part of this section explains how moving magnets within a coil of wire or moving coils of wire between the poles of magnets can generate great amounts of electric current. Without electricity our modern way of life would not be possible. Did you ever think how much you depend on a moving coil or a magnet? Can you imagine what it would be like if there were no electric current to serve you? Can you remember a time when the electricity went off in your home?

Producing Powerful Electric Currents

If you did the investigation on page 239, you produced enough electricity to move a tiny needle back and forth or to light a small bulb, and

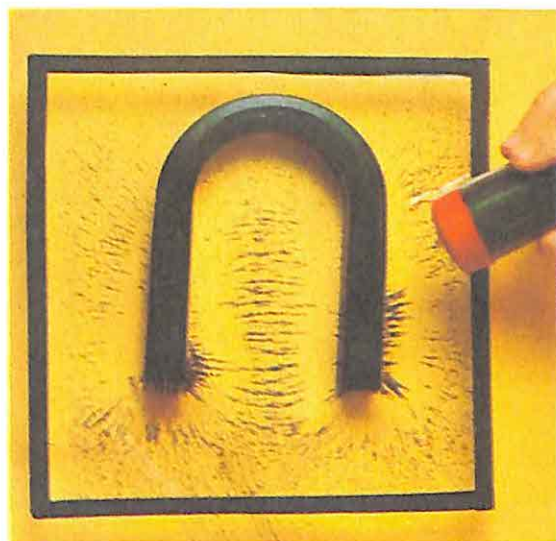


you know that the force of a magnet has something to do with the production of an electric current.

Perhaps you also have an idea of what is meant by a **magnetic field**. If not, you can observe the way magnetic force acts by using a magnet, some iron filings, and a piece of glass or plastic. Place the glass on top of the magnet, as shown. ● Sprinkle some of the filings carefully on top of the glass. Tap it gently. The iron filings collect along the **lines of force** of the magnet. They give you a visual image of a magnetic field (as shown in the picture).

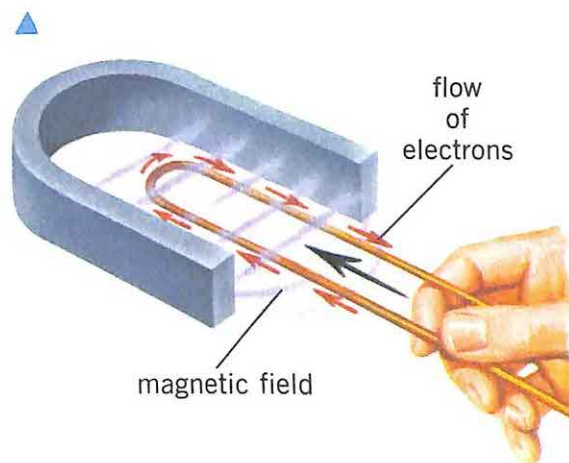
Notice that the strongest lines of force seem to be between the poles of the horseshoe magnet. Perhaps this explains why it is easy to produce an electric current by moving a wire between the poles. You are then moving it across the strongest part of the magnetic field. ▲

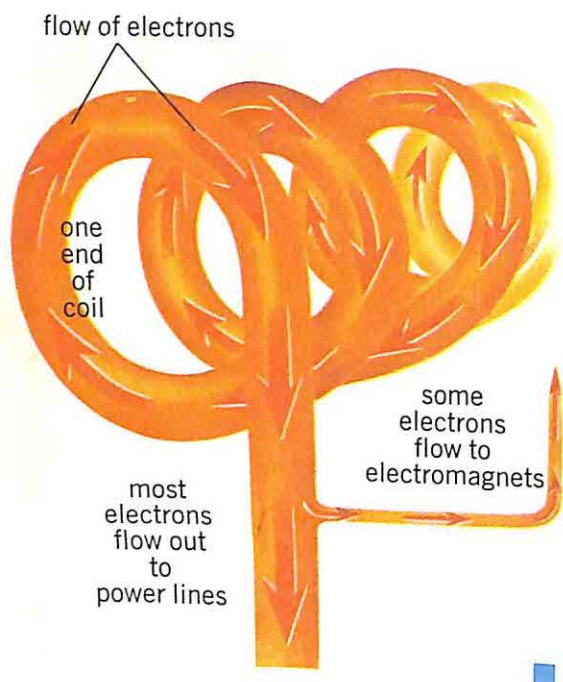
If you move a wire across a magnetic field, it seems as if the electrons in the wire are given a push; they flow through the wire and can move the needle on a meter. In order to keep the electrons flowing, however, the wire must be kept moving through the magnetic field. If the wire stops moving, the electrons stop moving. *If no work is done, electric current is not produced.* Of course, you could do it another way, as in the investigation on page 239. You could hold the wire steady, but what then would be required to move in order to move the electrons?



With a moving magnet and a wire, you have made a tiny generator produce a tiny current.

How can a larger current be produced? How can a current large enough to run an electric train or to light a city be produced? The results of the investigation on page 241 should give you a clue. When you think you have the answer, read on to find out how large electric currents are generated and to learn about one of the world's greatest dams.





only when a current flows through the coil, where does the electromagnet in a generator get the electricity to make it work?

At Boulder Dam, some of the current produced in the coil of the generator is shunted to the wires of the electromagnets, as shown in the diagram. ■ This keeps the magnetic field around the electromagnet quite strong. As the electromagnet spins, the electrons within the stationary coils flow out through wires in great quantities to supply the country with electrical energy to light homes and run machines.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

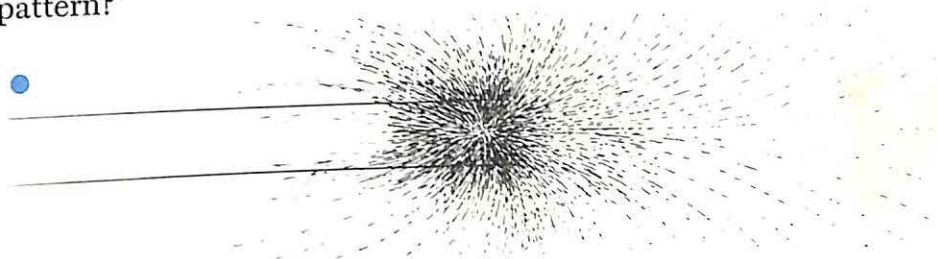
1. When a magnet is moved in a coil of wire
 - a. an electric current is produced
 - b. static electricity is produced
2. In order to generate electricity, work
 - a. must be done
 - b. need not be done
3. A greater flow of current is produced in *all but one* of these conditions. Give the one condition.
 - a. A magnet is moved faster in a coil of wire.
 - b. A stronger magnet is used.
 - c. A larger coil of wire is used.
 - d. A rubber rod is rubbed faster with a piece of wool.

B. Write a paragraph or two on this topic: Generating an Electric Current.

USING WHAT YOU KNOW

1. To make a small generator of electricity, you need a magnet and a coil of wire. What else is needed?

2. Below is a diagram of iron filings. ● What is responsible for the pattern of the filings? How would you change the pattern?



3. What is the difference between potential energy and kinetic energy?

ON YOUR OWN In the Laboratory

Get a bar magnet. Test its strength by using it to lift paper clips or nails.

Now make an electromagnet which is twice as strong as the bar magnet. How can you do it? How will you know the electromagnet is twice as strong as the bar magnet?

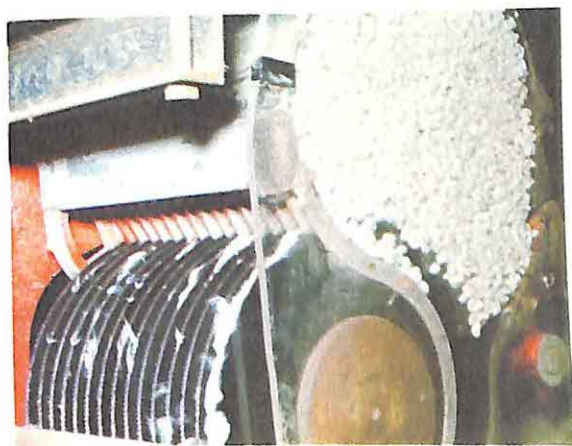
3. Electric Bells and Electric Motors

If you visit any factory, you will find some power-driven machines. Perhaps you will find some that push pieces of ore along by means of a screw or winding inclined plane. Perhaps you will find a machine with gears to separate fibers, as shown in the picture. ▲

These machines may be simple or compound, but the force which makes them work is not supplied by muscles as it was years ago. Perhaps the earliest factory machines were operated by muscle power. Men worked them, or else the force of animals walking on huge treadmills was used.

But muscle power was too limited; it took too long to get a job done.

Still later, the force of wind or the force of moving water turned wheels that operated machinery. As man gained more knowledge, he found newer and better sources of energy.



He learned to use steam engines to turn long shafts, as described in Unit Five. Today, however, most of the energy used to run machines in a factory is supplied in a different way. The energy is transferred from one place to another through wires. It is the energy of moving electrons.

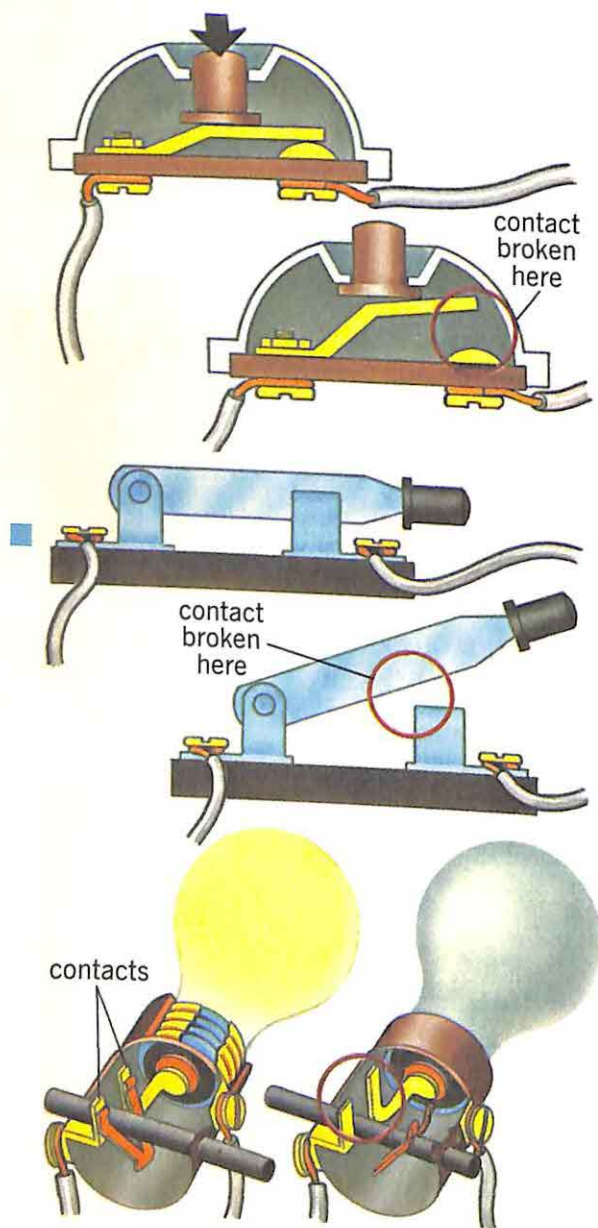
By pushing a switch, man can unleash this energy. When he pushes the switch he starts millions of tiny electrons moving through a circuit to do work for him. In our discussion of electric bells and motors, let us start with electrical switches. How do switches help man control the great energy of moving electrons?

The Purpose of Switches

The push button or switch on a lamp serves the same purpose as a knife switch. Look at the pictures of a doorbell button. ■ Compare them with the knife switch. Can you determine how the doorbell button works? When the button is pushed, the current flows through the circuit to ring the bell. When the button is released the circuit is broken, and the current stops. The electrons cease to move through the wires.

The next pictures show how a lamp switch works. ■ There are many different types of switches, but they all do the same thing. They make and break an electric circuit.

The moving electrons (current electricity) run motors. The motors operate the machinery of the factory or the simple and compound machines found in your home. Moving electrons make machines work. How do moving electrons move the parts of an electric bell or an electric motor? How are electric bells and electric motors similar? See for yourself by doing the investigations on the next three pages.



AN INVESTIGATION into the Similarity of Electric Bells and Electric Motors

Needed: an electric bell; a small electric motor

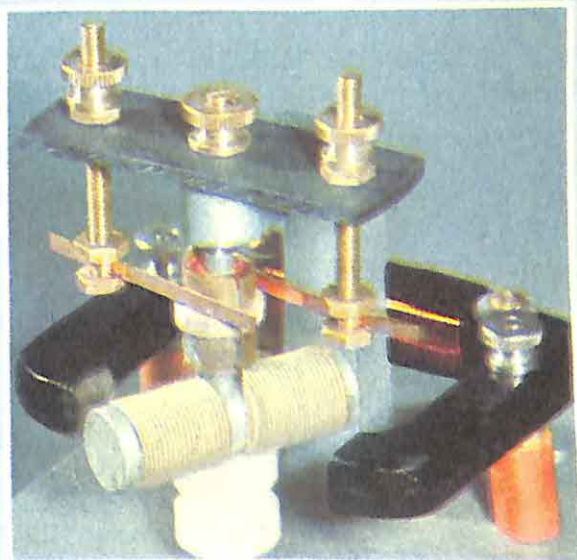
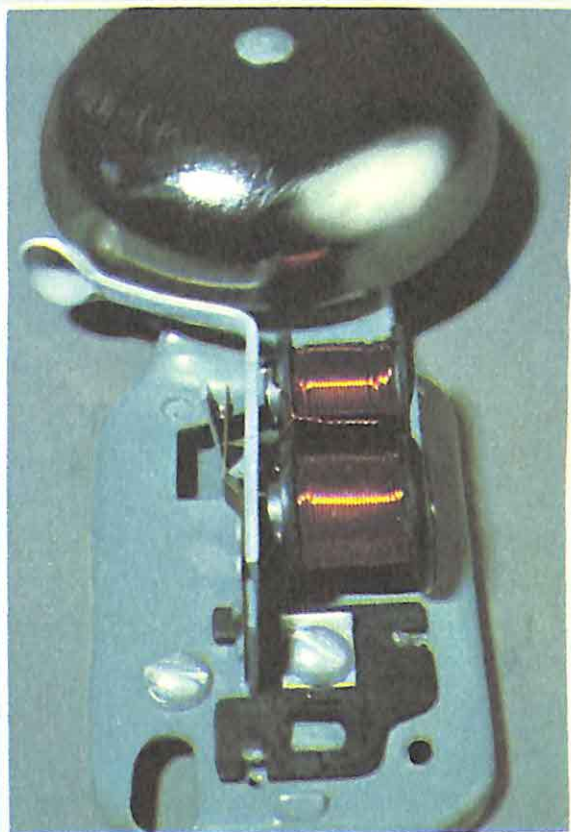
Take the cover off the front of an electric bell. ■ Look inside an electric motor. ● The pictures will give you an idea of how they are built.

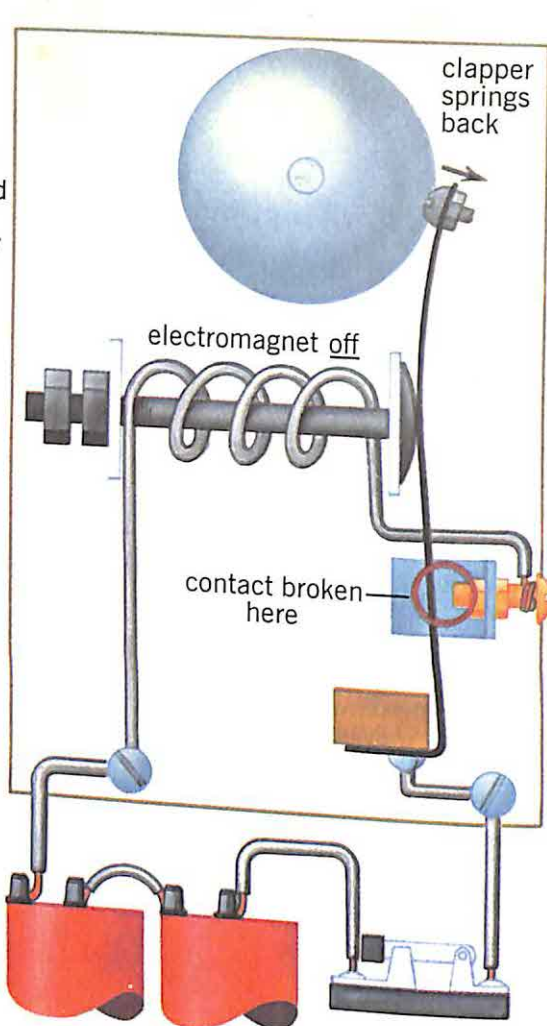
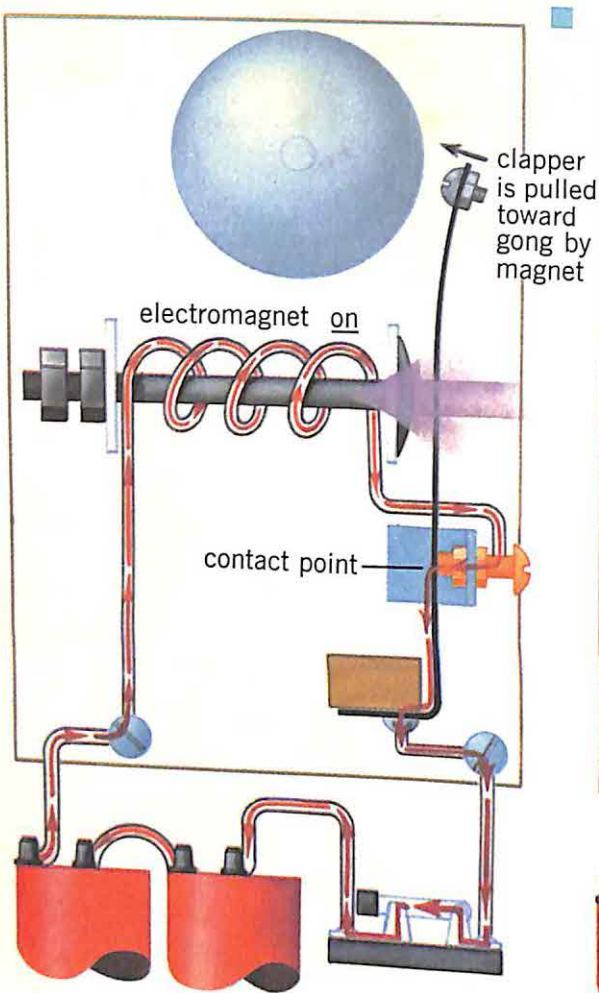
Look for something that is similar in both of them. Do you find an electromagnet in each? Sometimes there are several. They may have different shapes, but they each have a metal core with wire wound around it. You may recognize that the metal core is iron and that the pieces of iron with wire wound around them *are* electromagnets.

How are electromagnets used to ring a bell or to run an electric motor?

If you do not know, why not make a bell of your own, as shown on the next two pages? You will find it interesting, and you can use it to test how well you can put ideas and tools together.

Additional Investigation: Is the motor in the picture different from an electric generator? Do they both contain the same basic arrangement of parts?





An Explanation of an Electric Bell

With a source of electric energy, we can move electrons. We can direct the path of electrons to flow where we need electric energy to do work. Recall this basic concept: Work is done when an object is moved through a distance. Take a moment to think about this question: Is work done when an electric bell rings? What object is moved?

In the bell, electric energy produces a magnetic force in an electromagnet that attracts the bell clapper.

The current flows through the coils of the electromagnet and the electromagnet pulls the clapper. Then the clapper hits the gong. What happens to make the clapper move back and forth again, and again, and again, to make the bell continue ringing?

When the current is off, the electromagnet does not attract the clapper. (The soft iron stays magnetized *only* as long as the current is moving from the coil.) The clapper springs away from the gong. When the clapper springs away, the current goes on

again and the electromagnet attracts the clapper again. The clapper hits the gong again. This happens over and over. But why does the current keep turning ON and OFF?

Study the picture. ■ Do you see how the electromagnet pulls the clapper away from the contact point and breaks the circuit? When the circuit is broken, the electrons stop flowing. When the clapper touches the contact point again, it completes, or closes, the circuit. Once again electrons move through the circuit, and the electromagnet is on again.

The knife switch opens and closes the circuit. It allows the current to pass through or cuts the current off when you want the bell to stop ringing.

Now go on to examine an electric motor.

Electric Motors

Electromagnets perform an important role in electric motors. You can discover a great deal about how an electric motor works by making your own model. Follow the directions on the next two pages.

Motors—An Explanation

Large electric motors work on the same principle as the model motor shown on page 255 and also the model electric bell. In each case, the energy of moving electrons produces a magnetic force in an electromagnet. In the bell, the clapper moves because it is attracted to the electromagnet. In the

electric motor, the armature spins around because it is attracted by the poles of electromagnets.

In the model motor an electric current is sent through the electromagnets, under the blades of the armature. The stationary electromagnets attract the poles of the crosspieces on the armature only when the brush is touching the bottom of the armature. (See page 255.) When the armature contacts the brush, the circuit is complete, and current flows to the electromagnet. The electromagnet attracts the blades of the armature and the armature moves away from the brush, allowing the blades to coast until they are attracted to the electromagnet on the other side. Soon the armature is whirling about.

In larger, more powerful motors the armature may turn the blades of a fan or of other machines, such as washing machines, electric mixers, power saws, and factory tools.

More complicated electric motors use electromagnets *on* the spinning armature, as shown on page 249. Most of them use a more complicated electric circuit and a different arrangement of parts for more efficient operation.

Make a list of all the appliances that you can think of which use electric motors. It will probably fill several pages. Each year more new ones are produced. The electric can opener, the electric blender, and the electric shoe buffer all do jobs that were once done by muscles alone.

MAKING A MODEL: An Electric Motor

Needed: a piece of pegboard about 4 x 6 inches; a thin sheet of iron or steel (about 4 x 4 inches), perhaps cut from a can; two bolts, which fit the holes in the pegboard, about $1\frac{1}{4}$ -inch long; four nuts and four washers to fit the bolts; a strip of clean metal about $\frac{1}{2}$ -inch wide and 3 inches long; a spool of insulated bell wire; a piece of copper wire 4 inches long, bare at the end; four short bolts to fit the pegboard; six nuts to fit these bolts; a 6-inch metal strip; a pointed tool; metal shears

Study again the diagram of the bell on page 251. Recall that the electromagnet attracts the clapper, making it move. Now look at the diagram of a simple electric motor. ■ Electric motors are turned by electromagnets. You can make this simplified motor with the materials listed above.

Wind at least a hundred turns of the bell wire around each of the $1\frac{1}{4}$ -inch bolts, between two washers, as shown; the more windings the better. Use tape to keep the coils from unwinding. Leave about 6 inches of wire at each end for making connections.

Use the four nuts to attach both electromagnets to the strip of clean metal (cut 4 inches long) and to the pegboard, as shown. Attach the wires, as shown.

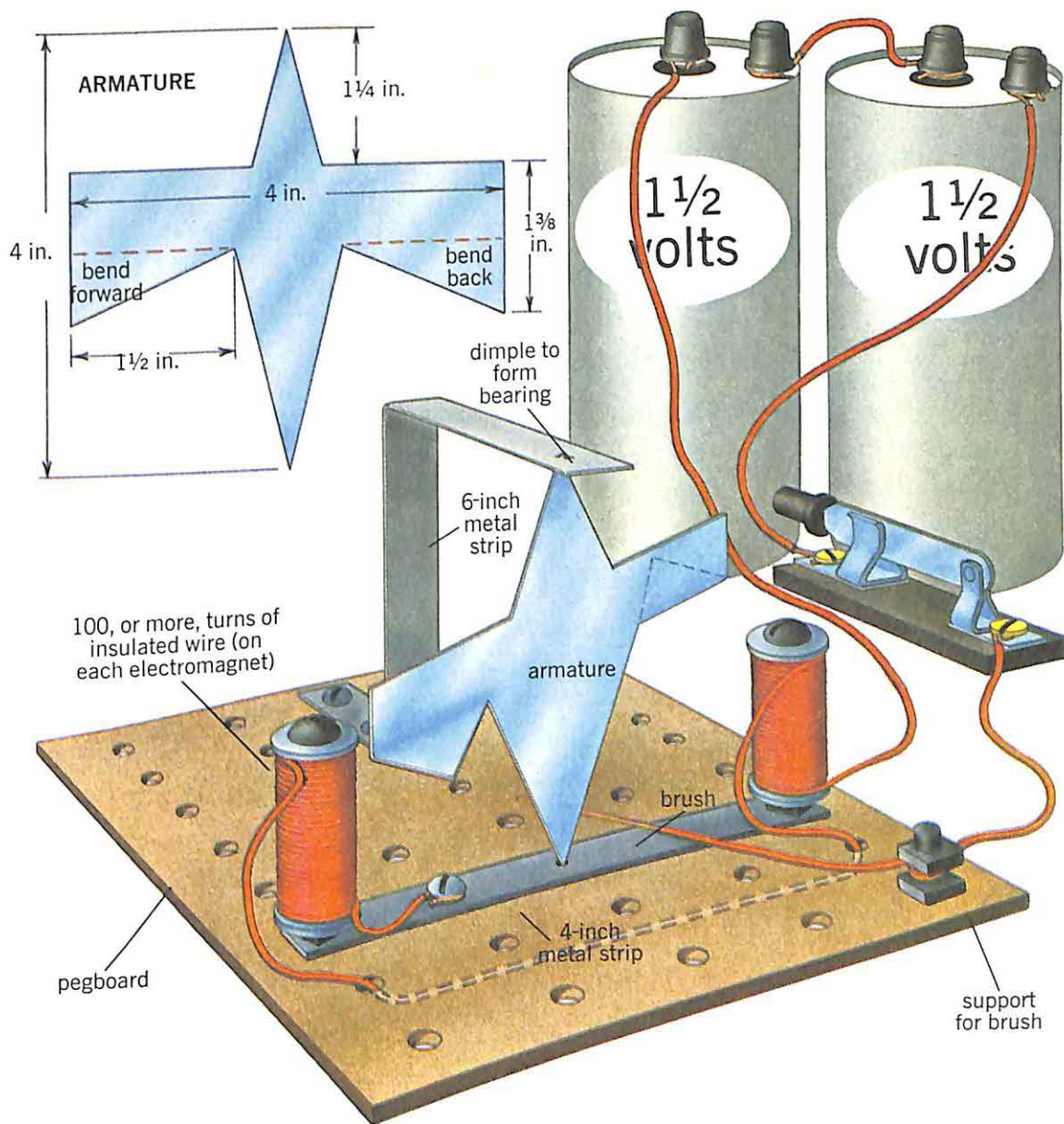
Use metal shears to cut the **armature** (är'mə-choör) from the piece of 4 x 4 thin steel. Watch out for sharp edges on the metal. Measure carefully so that it will clear the tops of the bolts. Bend one flap forward and the other backward, as shown. (It may be wise to get an adult to help you with this procedure.)

Use a pointed tool to make a small dent or cup in the strip of metal. This cup will serve as the upper pivot for the spinning piece of metal, called the armature. Make a similar pointed cup in the center of the bottom metal strip to serve as the lower pivot point for the armature.

Bend the 6-inch metal strip so that it forms a holder for the armature to spin in an upright position. Fasten it to the pegboard with two small bolts.

Attach the brush (4-inch piece of bare copper wire) to another small bolt, as shown. Connect a piece of insulated wire from the same bolt to the switch or to a dry cell. Adjust the brush so that it just touches the bottom angled part of the armature. It should touch only for a short time as the armature turns and only when the armature is in such a position that the crosspieces are not too close to the electromagnets.

Once the motor has been assembled, it must be connected to a source of electric energy. Dry cells, connected in series, are suitable for this purpose.



Connect the electromagnets and wires to two dry cells and a knife switch, as shown above.

Close the knife switch and give the armature a start in the direction of the points on the blades of the armature.

You may have to adjust the position of contact between the brush and the armature to get it to spin steadily.

Go to the library and get information about other electric motors. Do all motors work on the same principle?

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Electric motors and electric bells would not be able to operate without

- a. switches
- b. electromagnets

2. Different kinds of electric switches are used to complete an

- a. electric circuit
- b. electromagnet

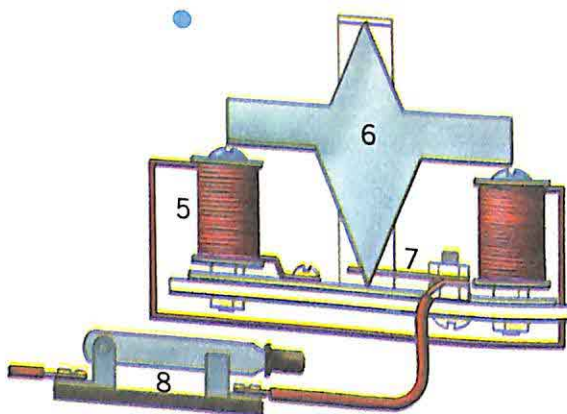
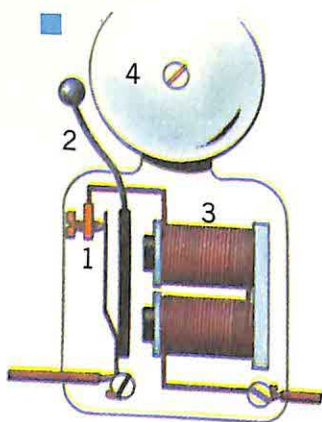
3. The part of an electric motor that acts like the contact point on the electric bell is the

- a. brush
- b. electromagnet

B. Write a paragraph or two on this topic: How an Electric Motor Works.

**USING WHAT
YOU KNOW**

A. Below are diagrams of an electric bell and an electric motor. Note the numbers which lead to different parts of each. Name each part and write what each part does. ■ ●



B. Compare the electric motor (page 249) with the generators (page 240).

- 1. How are they similar?
- 2. How are they different?



4. Electric Signals

At the top of this page are shown ways people have used to communicate with others some distance away. ▲ What are some other ways to communicate quickly at even greater distances, such as with other countries throughout the world?

We can, of course, send letters by jet plane. A jet plane crosses the continent in 4 hours, reaches France (from New York) in 7 hours, or approaches Hawaii (from San Francisco) in 8 hours; but there is a way to send a message much faster than this. In fact, you can send a message with the speed of light, about 186,000 miles per second.

In your school, how many different ways are used to send messages? Are they conveyed by direct speech, by delivery of a hand-written note, by electric energy through a wire, or by radio waves?

Have you ever made an announcement on a loudspeaker or called a friend on the playground?

Have you ever carried a written message from your teacher to the teacher in another classroom?

Does your classroom have a telephone or an "intercom" system?

Is there a radio or a television set in your school? These can carry voice messages over a long distance. The first electrical devices for carrying long-distance messages, however, could not transmit the human voice. They carried messages in code.

Messages by Code

A telegraph sends messages by a code. Are code messages used in your school? Here is a clue: What is the signal for dismissal? for a fire drill? It is probably a gong or a bell which conveys a message by a kind of code. A button is pressed in the office, and the gong rings. One ring may mean dismissal; two rings may mean a fire drill. Three rings may mean something else—what do they mean in your school?

Today a message can be sent by telegraph across the country faster than you can say "one." In fact, a message sent at a speed of 186,000 miles per second (the speed of light) could go around the earth in about one-seventh of a second. How does the telegraph work?

Study the telegraph shown. ■ Notice that there are really three separate parts:

1. A *telegraph key* that opens and closes an electric circuit to control the electric current.

2. A *sounder bar* that produces a clicking noise each time the circuit is closed by the key. The time lapse between clicks establishes the code.

3. A *source of electricity* (in this case, two dry cells) that provides an electric current.

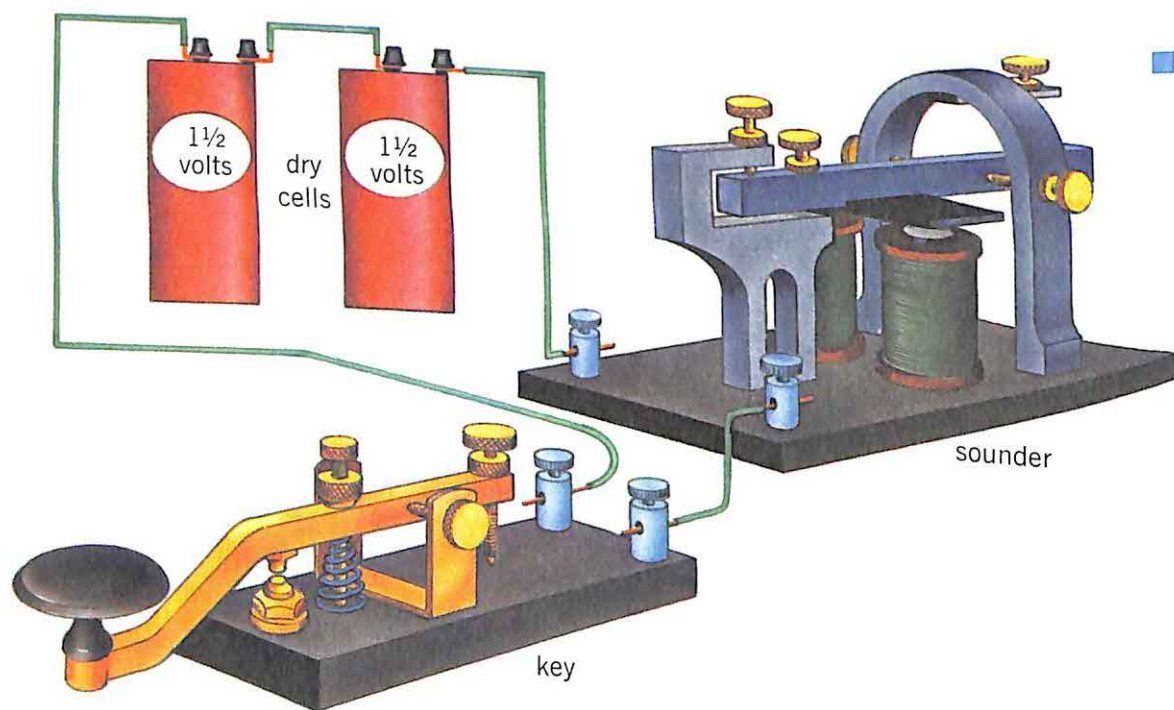
Does the key remind you of a switch (page 248)? Each time the key is pressed down, the electric current flows in a circuit. When the key is released, the current stops flowing.

Now look at the sounder. The metal bar moves up and down and makes a sound.

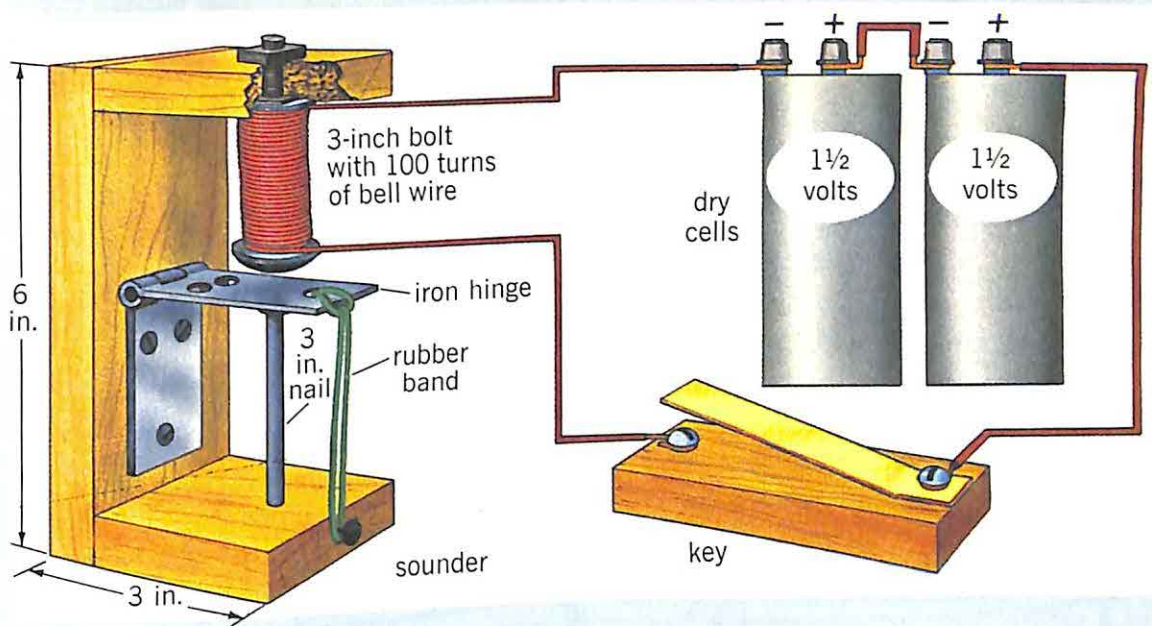
What makes the metal sounder move up and down? Notice the electromagnets below the sounder bar. Each time the key is pressed down, electric current flows through the electromagnets, and they attract the iron crosspiece on the sounder bar. As the sounder moves up and down, it makes a clicking sound as it hits the screw above or the frame below. These clicks are the code for a message, as you can find out if you make your own simple telegraph.

A Model Telegraph

Why not make your own model of a telegraph? You can use it to send messages to your friend across the yard or to your brother or sister upstairs. Directions for making the telegraph are on the opposite page.



MAKING A MODEL: A Telegraph



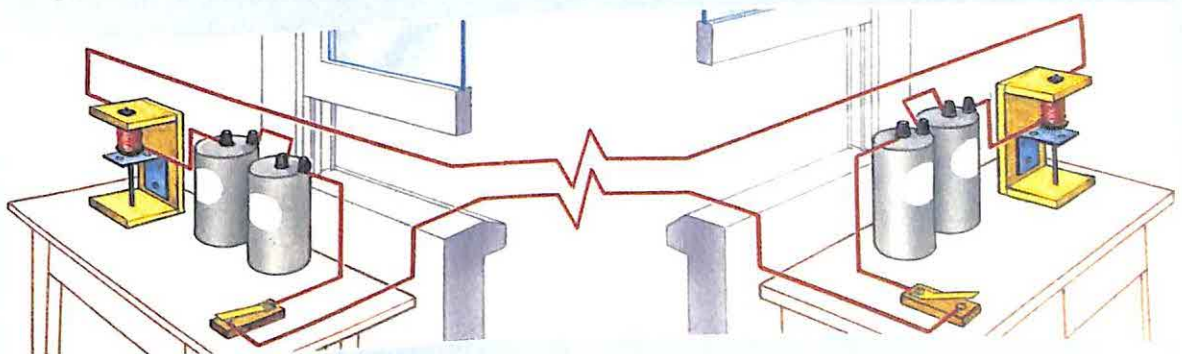
Needed: all the materials shown in the diagram of a hinge telegraph ■

Construct a telegraph sounder, using the simple materials shown in the diagram. By turning the nut at the top, you can adjust the height of the electromagnet so that the hinge is in range.

If the hinge sticks to the bottom of the bolt when the current is turned off, place a thin rubber band between the hinge and the base, as shown.

Make the key by using shears to cut a strip of metal from a tin can. You can protect yourself from the sharp edges on the metal strip by putting tape on the edges.

If you make two telegraph sets, you will be able to communicate with a friend some distance away. The diagram shows how the two sets should be wired. Remember, the key closes and opens the circuit. The person receiving the message always holds his key down.



INTERNATIONAL MORSE CODE

A.—	G—..	M—	S...	Y—.—	5.....
B—...	H....	N—.	T—	Z—..	6.....
C—....	I..	O—	U...—	1.—.—	7—...
D—..	J.—.—	P.—..	V...—	2.—.—	8—...
E.	K.—.	Q—...—	W.—	3...—	9—...
F...—	L.—..	R.—.	X—...—	4...—	0—...
	(.)—...—	(,)—...—	(?)—...—		

SHORT EXPRESSIONS IN INTERNATIONAL MORSE CODE

K.—.	End of message, go ahead and answer	AR.—...—	Sign off — no acknowledgment necessary
R.—.	Message received and understood	N—.	Negative — no
V...—	From	A.—	Affirmative — yes
		IMI...—..	Repeat

Using a Telegraph

If there were two telegraph sets in separate rooms, how would you send a message from one set to the other? You would need a code. Of course, you could make up your own, but why not use the International Morse Code, which most telegraphers use and which is shown on the top of this page. The letters are represented by various combinations of dots (·) and dashes (—). To send a "dot," press the key and let go immediately. To send a "dash," press the key and hold it for about the time it takes to say "dash." You may think of a dot as a short interval between clicks and a dash as a longer interval between clicks (about three times longer). You read the code by listening to

short and long intervals between clicks. After some practice you should be able to recognize the different combinations of dots and dashes easily.

Translate a word message into code and send it with your telegraph. Perhaps you might send this one: "Well done, well done."

Check with one of your classmates. How successful were you in sending the code, and how successful was he in "reading" it? Try other messages until each of you can understand the messages sent in the dots and dashes of the Morse code. After you have practiced for a while you will be able to gain speed when sending and receiving. Some of the short expressions at the bottom of the code will also help you to gain speed.

Suppose you were to receive this message in code. Can you translate it?

/.-.-/.../.-./ /.-/.-./
 /-.../-.../.../ /-.../-.../.../
 /.-/.../-./.../
 /.../-.../.../-.../-.../...-./

The telegraph was invented by Samuel F. B. Morse. Sending code messages over wires was a great improvement in communications, but it is much better to hear the actual *voice* of a friend. Many scientists considered the idea, but Alexander Graham Bell made it happen.

/.-.-/.../ /.-./.-./ /-.../
 /-.../ /-.../-.../-/
 /.../.../-.../-.../-.../-.../-

Voices from Afar

Long-distance telephone calls can be made very rapidly on the special telephone shown in the picture. • This particular telephone is similar to the one on the desk of the President of the United States.

By inserting a particular card into a slot, the President is able, in an instant, to talk to leaders in London, or Paris, or Rome, or Moscow.

Many more of these modern telephones will be in use during the next few years. Some business organizations are now using them as a rapid

method of contacting branch offices around the world. Notice the slot for inserting prepared cards to get the numbers most often called, and the pushbuttons that have replaced the round dial.

Think of the many ways in which the speed of communicating by telephone can help us. It can be used to report an accident, to call the doctor, to report a fire, to order groceries, to catch a criminal, or to save a life.

How does the telephone system relay a message such a long distance in such a short time?

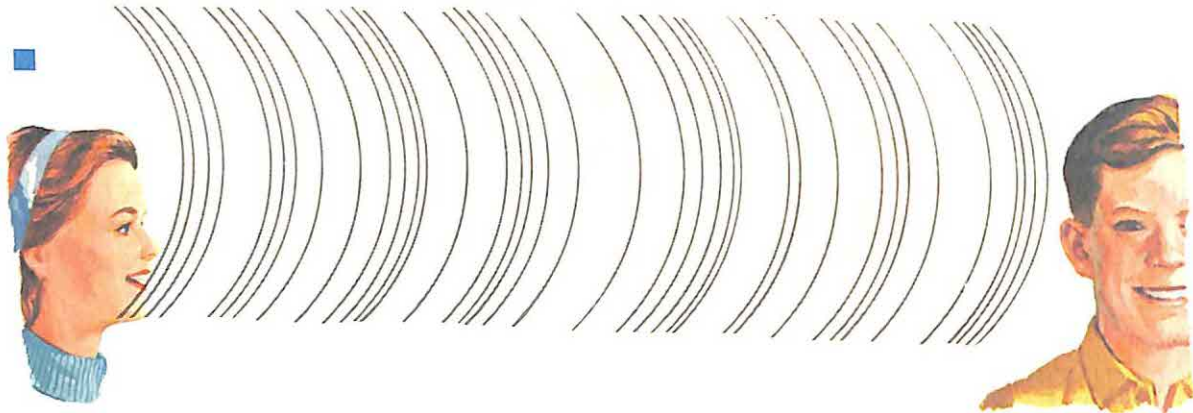
First, let us look at a telephone; it has three important parts.

1. A *transmitter* (trans-mit'er) that picks up your voice and then translates the sound into **electric impulses** (the message).

2. A *wire* that carries the message.

3. A *receiver* that receives the electric impulses (message) and translates them back into sound for someone else's ear.





What Happens to Your Voice

In order to produce the sound of speech, you must cause particles in the air to move in wave patterns called sound waves. ■

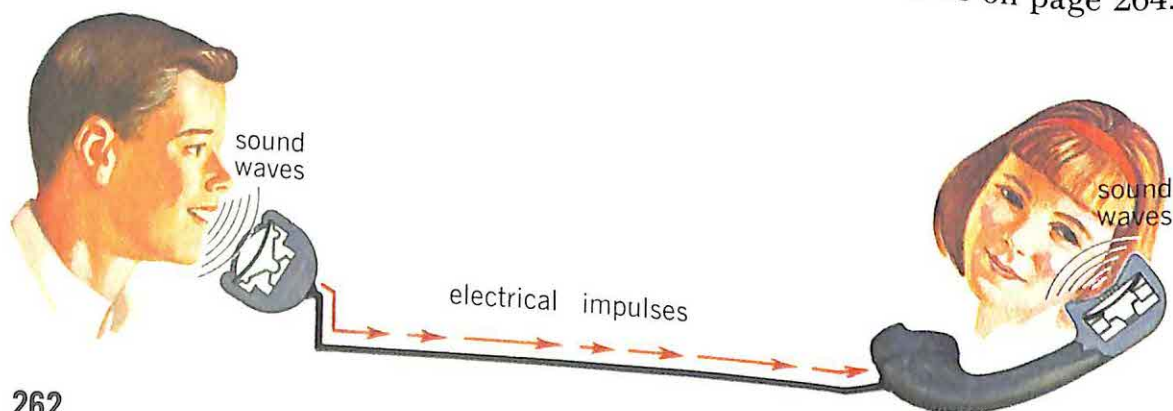
These sound waves cause a small thin disk in the transmitter of the telephone to vibrate. The vibrations have the same pattern as the sound waves produced by your voice, and the "message" of your voice is transmitted along a wire but not as sound. Sound vibrations can travel along a solid wire for only a short distance, whereas an electric current can travel a very long distance through a wire. The object then is to change the sound waves into electric impulses, which then travel through the wire in the same pattern as that of the sounds produced by your voice. ●

When the electric impulses reach the receiver, a thin metal plate vibrates to produce the same pattern of sound waves as the ones spoken. Your friend's ear then receives the sound.

To find out how a telephone transmitter works, make a simple one of your own. Perhaps the directions on the opposite page will suit you. If not, invent your own ideas and tools.

Changes in the Word "Hello"

When you call a friend and say "hello" into the transmitter of the sugar-box telephone, what happens? Can you explain how the message travels from your vocal cords to the transmitter, over the wire to the receiver, and from the receiver to your friend's ear? Perhaps your explanation might be as follows on page 264.



MAKING A MODEL: A Simple Telephone

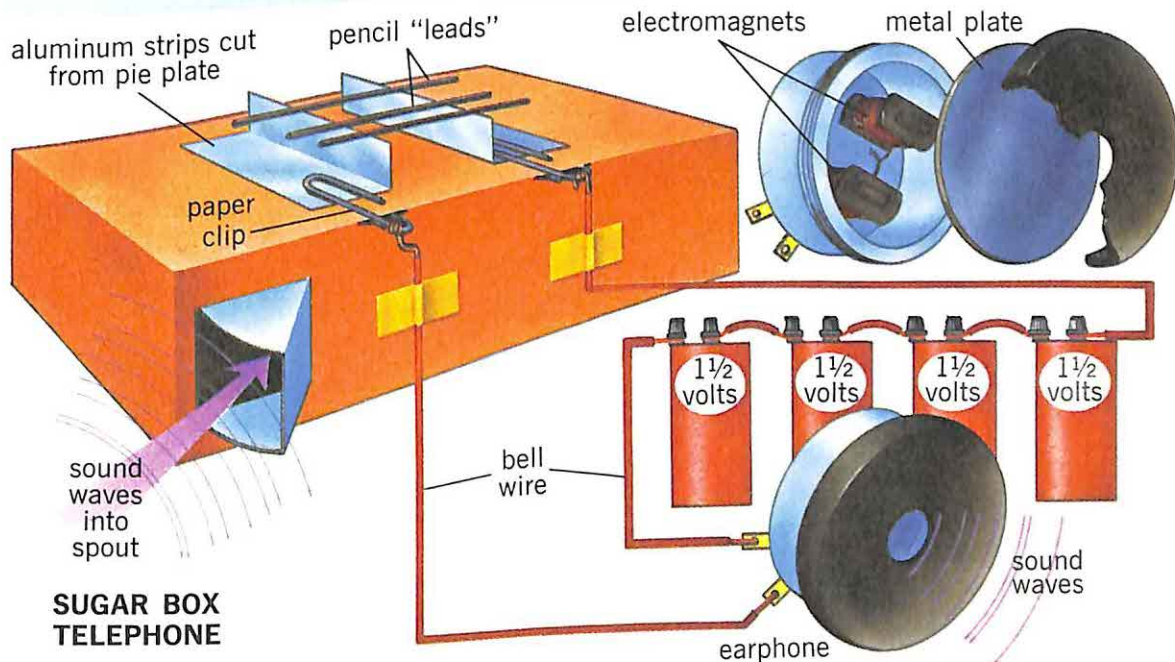
Needed: 2-pound sugar box, and other materials shown in the diagram

Cut two small pieces from the bottom of the aluminum-foil pie plate. Bend each piece near one end, and fasten it to the front surface of the box by inserting paper clips, as shown. Place the two or three pieces of pencil "lead" (really, graphite which is a form of carbon) across the tops of the aluminum strips, as shown. ■ This completes the telephone transmitter.

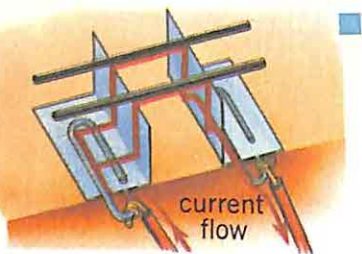
For a receiver, use an amateur's radio headphone or a discarded telephone receiver. ■ Use four $1\frac{1}{2}$ -volt dry cells connected in series or one 6-volt cell in the circuit.

After you have attached all of the wires and batteries as shown, test your "telephone." Ask a friend to take the receiver some distance away and to listen while you talk into the open pouring spout. Try changing the number of pencil carbons, and the distance between your mouth and the spout, until you get good results. Does the telephone transmit your voice? What happens to the pencil carbons when you talk into the spout? What happens to the electric current in the circuit?

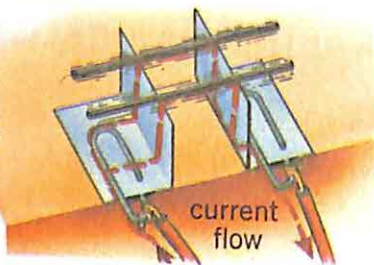
Unscrew the plastic cover of your headphone and examine the inside carefully. ■ Do you find an electromagnet? What do you think is the purpose of the electromagnet?



no voice —
steady flow
of current



sound waves
cause pencil
carbons to
vibrate,
producing
uneven spurts,
or electrical
impulses

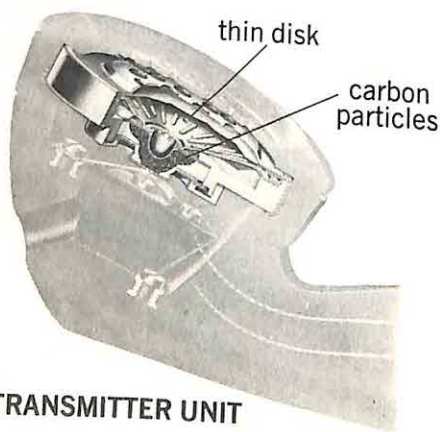


Vibrations set up by your vocal cords caused the sugar box, aluminum strips, and pencil carbons to vibrate. As the pieces of carbon vibrated, they “danced” up and down on top of the aluminum strips “in time” to the pattern of vibrations produced by the sound of your voice. As the carbons moved, they changed the steady flow of electrons through the circuit into strong and weak spurts of electricity, or electric impulses. ■ These electric impulses move along the wire to the receiver where they cause the electromagnet to become stronger or weaker, in patterns which match perfectly the sound waves produced by your voice. As the strength of the electric impulse varies, the strength of the electromagnet varies. The pull of the electromagnet on the thin metal disks varies as well.

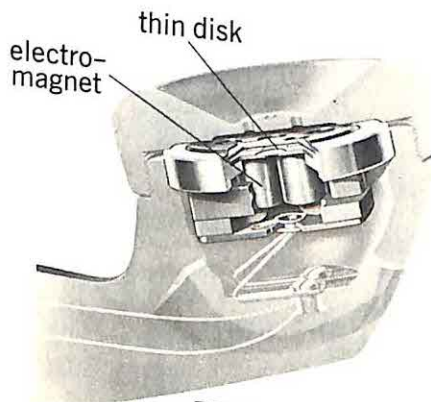
In this way, the disk in the receiver vibrates back and forth “in time” (in the same pattern) with the sound waves which began in your voice box. Your friend hears your “hello.”

What happens when you say “hello” to your friend over a modern telephone, like the one at home or in the school office? Is it the same as the sugar-box telephone?

Look at the diagram of a modern telephone shown below. ● The transmitter and receiver are both in the part that is lifted up by the hand. Compare the receiver unit with the diagram of the headphone on page 263. To what part of the diagram on the same page would you compare the transmitter below? You can find out more about the modern telephone by doing the investigation on the opposite page.



TRANSMITTER UNIT



RECEIVER UNIT

AN INVESTIGATION into a Modern Telephone

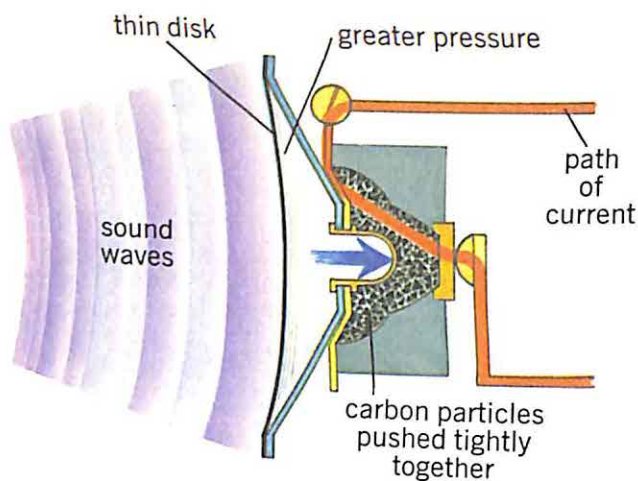
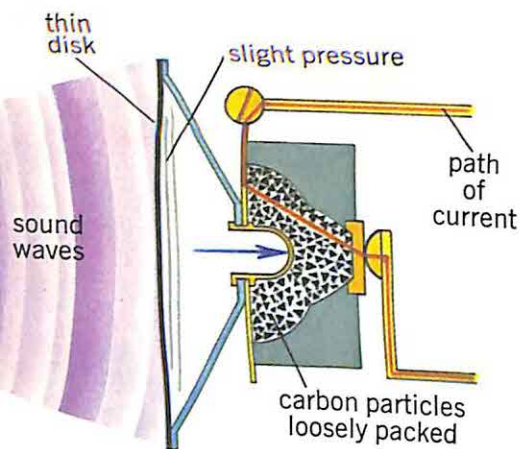
Needed: a modern telephone. DO NOT TAKE APART A TELEPHONE THAT IS IN SERVICE. Your teacher may be able to borrow one for this purpose by calling the local telephone business office

First, lift the receiver of the telephone from the cradle, and unscrew the cover from the mouthpiece. Take out the small unit just inside, as shown. ■ If the unit is stuck inside the mouthpiece cap, ease it out gently with a small screwdriver. This piece, about the size of a cookie, is the transmitter; and, of course, it works more efficiently than the sugar box, aluminum strips, and carbons that you used in making a model telephone. Examine the holes on top. Do you see anything inside that might vibrate? Look at the bottom of the tiny transmitter, and notice the small piece that is sticking out.

Now, in the same way, open the receiver. ● Tilt the receiver down so that the small unit falls into your hand. On some models, the unit is attached to a wire and cannot be taken out very far. Again, look into the holes. Do you find a plate that could be made to vibrate? Touch a steel paper clip to the side of the receiver. ▲ What happens?

The receiver is very much like the headphone that you used with the simple telephone model.





The Modern Telephone

The transmitter and receiver of a modern telephone are sealed units, and they cannot be taken apart easily. Use your imagination to visualize, with the help of the diagrams, what is on the inside of the transmitter. ■ You can also refer to the diagram on page 264. Notice the thin metal plate, or disk, inside the holes, which vibrates with the same pattern as your voice waves. Behind this disk are fine particles of carbon. These particles are equivalent to the two pencil carbons on the pieces of aluminum. As the disk vibrates, the carbon particles move closer together and then farther apart.

In the diagram on the left, for example, a fairly weak sound wave is hitting the thin disk, and because of its small force, is not causing the disk to move very much. ■ Therefore, very little pressure is being applied to the carbon particles; they remain loosely packed. It is not possible for a very large electric current to pass through

them. On the other hand, in the diagram on the right, a stronger sound wave is hitting the disk, pushing it inward with greater force. ■ Since they are under much greater pressure, the carbon particles are pushed closer together. When they become more tightly packed, they become a better conductor of electric current, as shown. A stronger electric impulse is therefore allowed to pass through the wire.

When the particles are closer together, they are said to be compressed. When they are farther apart, the volume of carbon particles expands. This compression and release of the carbon particles changes a steady current to electric impulses that travel along the wire. The telephone receiver changes the impulses back into sound waves that the listener can hear.

The telephone is a valuable aid. Raise the receiver and dial a number. Almost in an instant the connection is made, and your voice is transmitted with the speed of light to your friend.

**BEFORE
YOU GO ON**

A. Below are diagrams of a telegraph set, and a telephone transmitter and receiver. ● ▲

1. Note the numbers which lead to different parts of the telegraph set. In your notebook name each part and write what each part does.

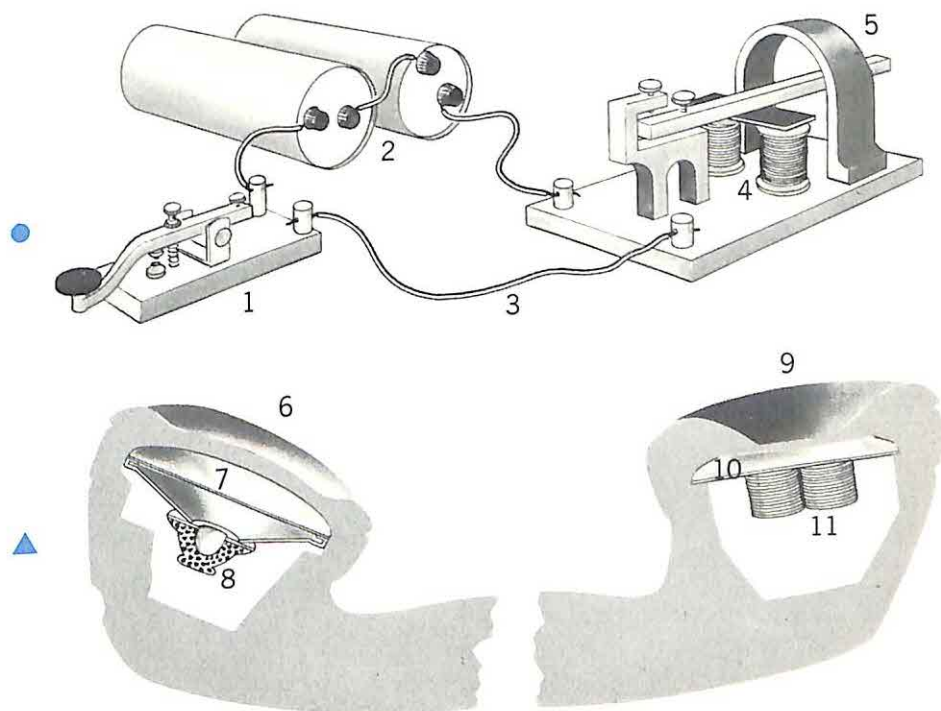
2. Name each numbered part of the telephone transmitter and receiver and write what it does, in your notebook.

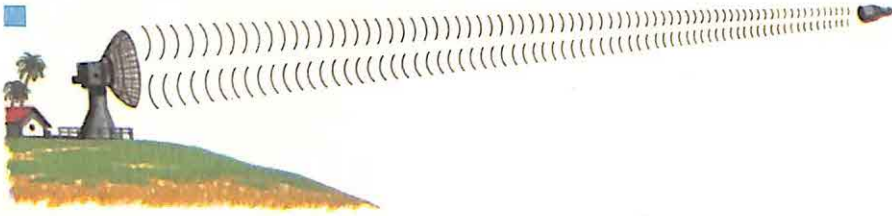
B. Write a paragraph or two on this topic: How a Telephone Works.

**USING WHAT
YOU KNOW**

Look again at the diagrams of a telephone transmitter and receiver. ● ▲

1. How are the transmitter and receiver similar?
2. How are they different?





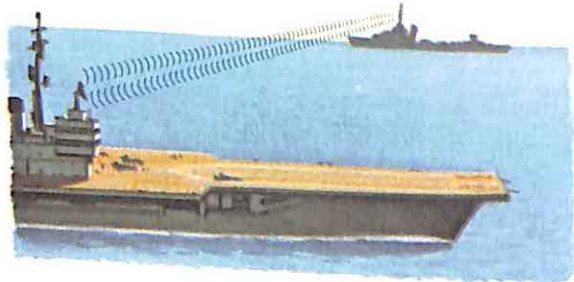
5. Relays Without Wires

High in a space capsule, an astronaut talks to his ground crew. ■ Aboard a destroyer, the captain reports to his admiral on the flagship, many miles away. ● He turns a knob, speaks into a kind of transmitter, and the admiral hears the captain's voice. At home you turn a knob and listen to the news the same way.

The development of the radio was one of the greatest advances in technology. The first long-distance radio transmitter was built by Guglielmo Marconi. In 1901 Marconi constructed a sending station at Cornwall, England. He then sailed to Newfoundland and set up a receiving station where he received the first transatlantic signal, the letter "S" in Morse code. From that time on radio has steadily improved.

How does a radio work? How can the pattern of a human voice be carried without wires for long distances?

Marconi and other engineers might never have invented radio communication had it not been for the discovery by another great scientist of the force around a wire. See for yourself what this force can do by doing the investigation on the opposite page.



A New Kind of Wave

A compass needle is really a tiny magnet. The needle moves when an electric current flows through a nearby wire.

Iron filings are attracted by magnetic lines of force, but they can also be lined up by electric current flowing through a nearby wire. When the electric current flows through the wire, what is produced around the wire?

The Danish scientist Hans Oersted (ûr'sted) observed the action of a compass which lay near a wire through which an electric current was flowing. After repeating his observation many times, he concluded that: *Whenever a current flows through a wire, a magnetic force is produced around the wire.* The magnetic force field can cause iron filings to line up. A wire with an electric current flowing through it acts like a magnet; it can move the magnetic needle of a compass even though there is only air between. Notice then that the

AN INVESTIGATION into a Force from a Wire

Needed: insulated bell wire; a dry cell; a plastic lid; iron filings; a small compass

Attach one end of a 2-foot piece of insulated bell wire to one of the poles of a dry cell. Place the plastic lid over part of the wire, so that an air space is left between the wire and most of the surface of the lid. Sprinkle some iron filings onto the lid near the wire, and tap the lid several times. Notice what happens to the iron filings.

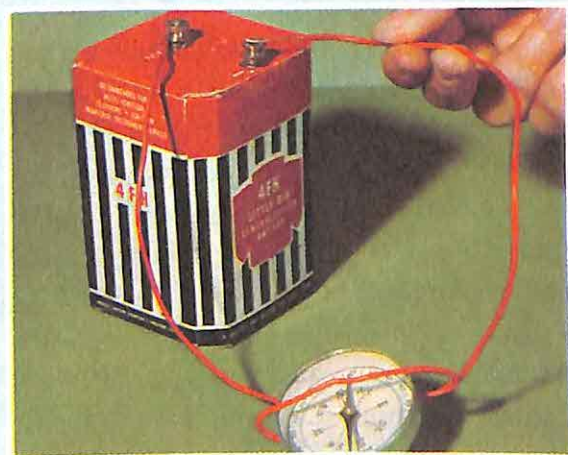
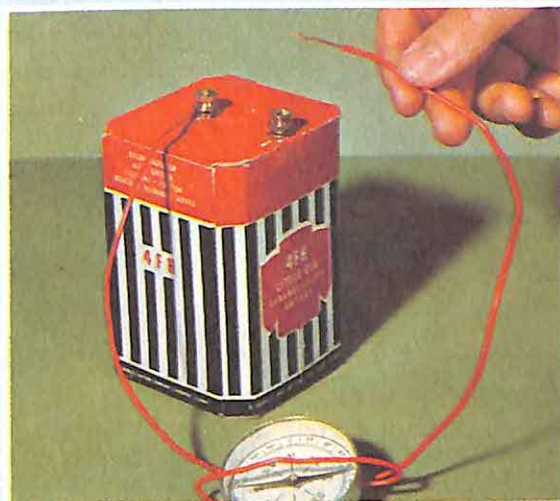
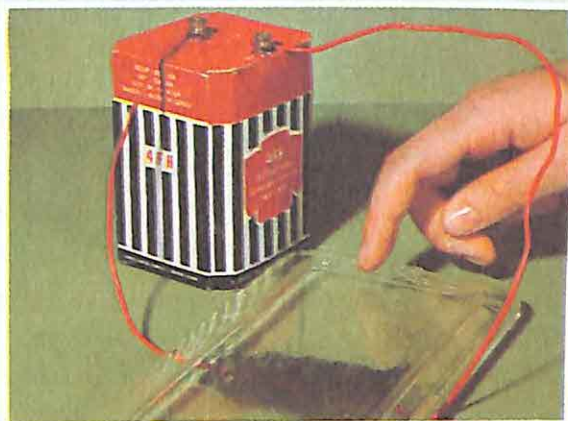
Now attach the other end of the wire to the other pole of the dry cell (as shown), making a complete circuit, so that an electric current travels through the wire. Again tap the lid several times. ■ What happens to the iron filings? What force is present in the air space between the wire and the filings? Disconnect the wire to save your dry cell and remove the lid and filings.

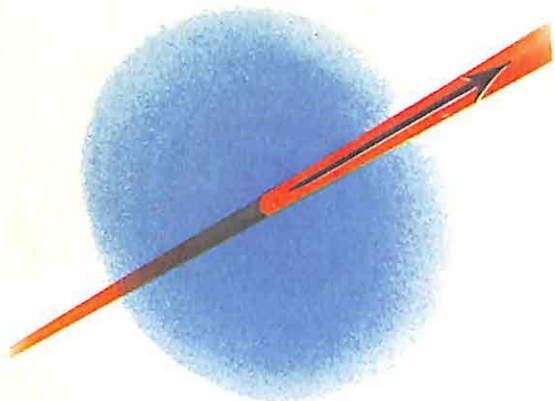
Make a single coil with the same wire, and hold a small compass in the middle of the coil, as shown. ● Again connect the wire. ▲ What happens to the compass needle? Try this several times, placing the coil so that it forms different angles with the needle. What happens?

Does it happen all the time?

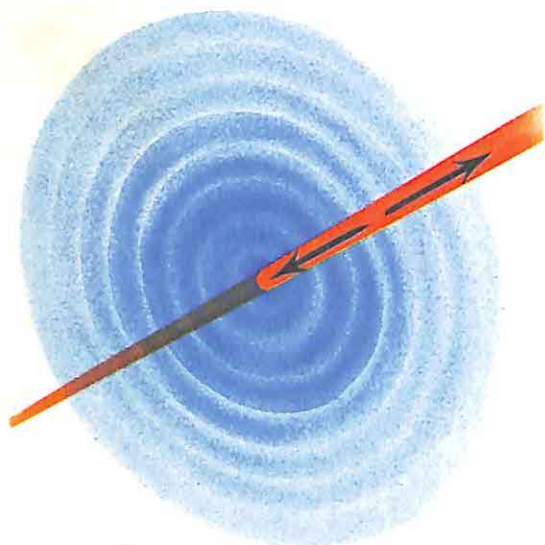
What kind of force makes the needle move?

Does the force extend through the air? How do you know?





Electric current moving along a wire in one direction sets up a magnetic field around the wire



Electric current moving quickly back and forth along a wire sends out electromagnetic waves in all directions

magnetic force can extend through air or through a vacuum. The diagram at the top shows part of the magnetic force field that occurs when an electric current moves through the wire in one direction, as in the investigation on page 269. ■

You may think of radio waves as *waves through a magnetic force field*. Radio waves are **electromagnetic waves** produced when an electric cur-

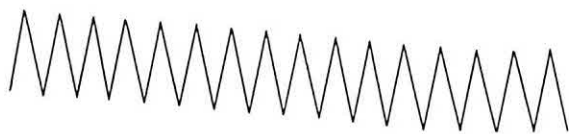
rent moves *back and forth* in a wire, as in the bottom diagram. ● The current must move back and forth (must change direction) in the wire very fast, as often as one-half to one million times a second.

Once the concept of how radio waves are produced was understood, it was possible to learn how to relay a "voice pattern" with radio waves.

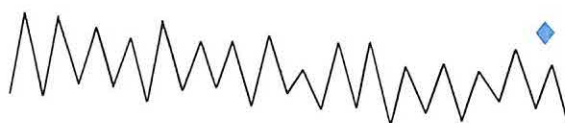
Patterns of Sound

The sound of your voice does not go through the wires of a telephone; the vibrations of your voice are changed into electric impulses and are transmitted in patterns of strong and weak impulses that match the patterns of vibration of your vocal cords. In transmitting by radio, the pattern of vibrations is carried by electromagnetic waves. The pattern is transferred to the electromagnetic waves (radio waves) by the action of sound waves on the microphone.

Look at the diagram of the electromagnetic waves which do not carry a voice pattern. ▲



When electromagnetic waves carry the pattern of your voice, they are changed to resemble those shown in the next diagram. ◆

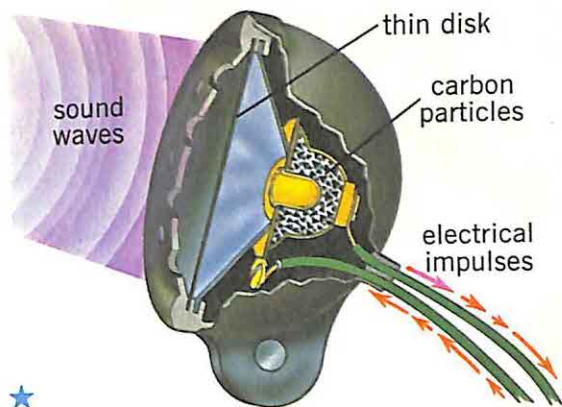


How are radio waves transmitted and received? What must be done to make the waves strong enough to travel a long distance?

In transmitting by radio, you talk into a microphone. The vibrations of your vocal cords set up vibrations, in the microphone, which produce electric impulses. There is little difference between the microphone and the telephone transmitter. The diagram on the right shows one kind of microphone which you can compare with the telephone transmitter.★ (See page 264.) In the telephone, electric impulses move through wires. In radio transmission, the pattern is transferred to the electromagnetic waves.

How are radio waves transmitted and received over long distances?

The electromagnetic waves are sent out by the radio transmitter which can produce waves powerful enough to travel many miles. These waves

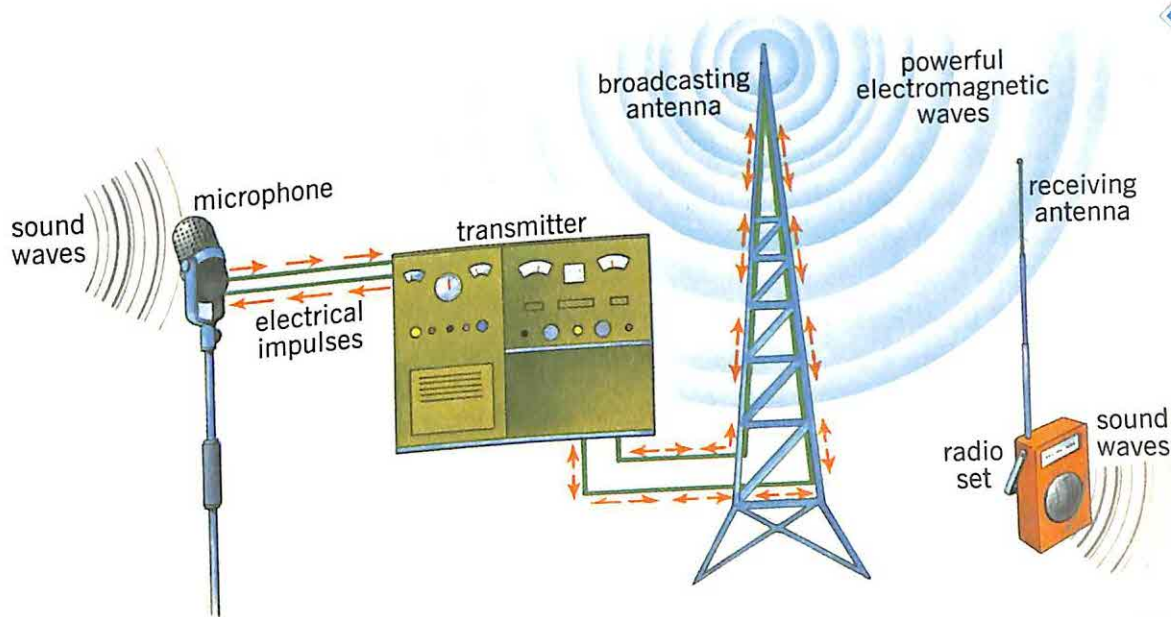


spread out in all directions from a wire called the **antenna**, which is situated high on a tower. In the illustration at the bottom of the page, you can see the important steps in sending strong radio (electromagnetic) waves.◆

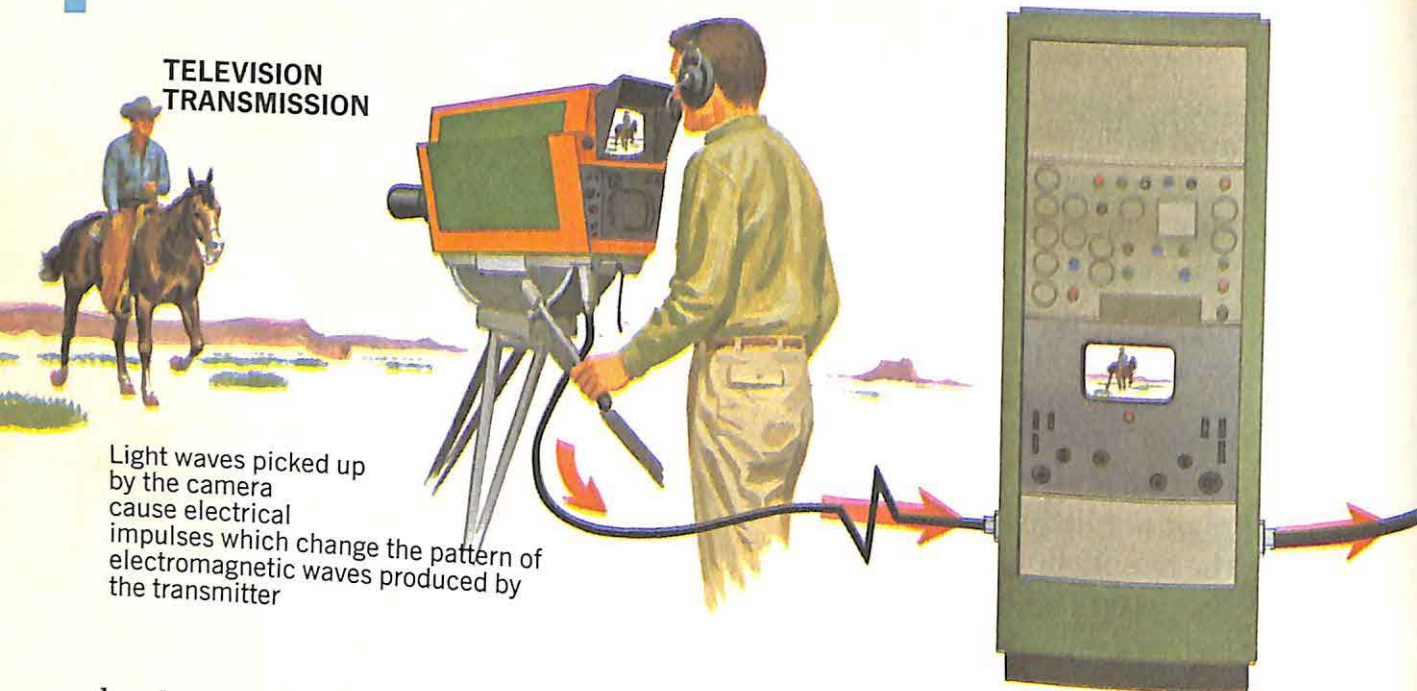
Where do these strong electromagnetic waves go?

Radio Reception

Perhaps your parents have described an old-style radio to you. If



TELEVISION TRANSMISSION



Light waves picked up by the camera cause electrical impulses which change the pattern of electromagnetic waves produced by the transmitter

they have, you may have heard about the wires which acted as the receiving antenna. The radios found in homes today still act as a receiver; they receive with an antenna the electromagnetic waves sent out by a transmitter, but the antennas of today are much smaller and more compact.

The pattern of these waves is transferred to sound waves by the speaker in your radio.

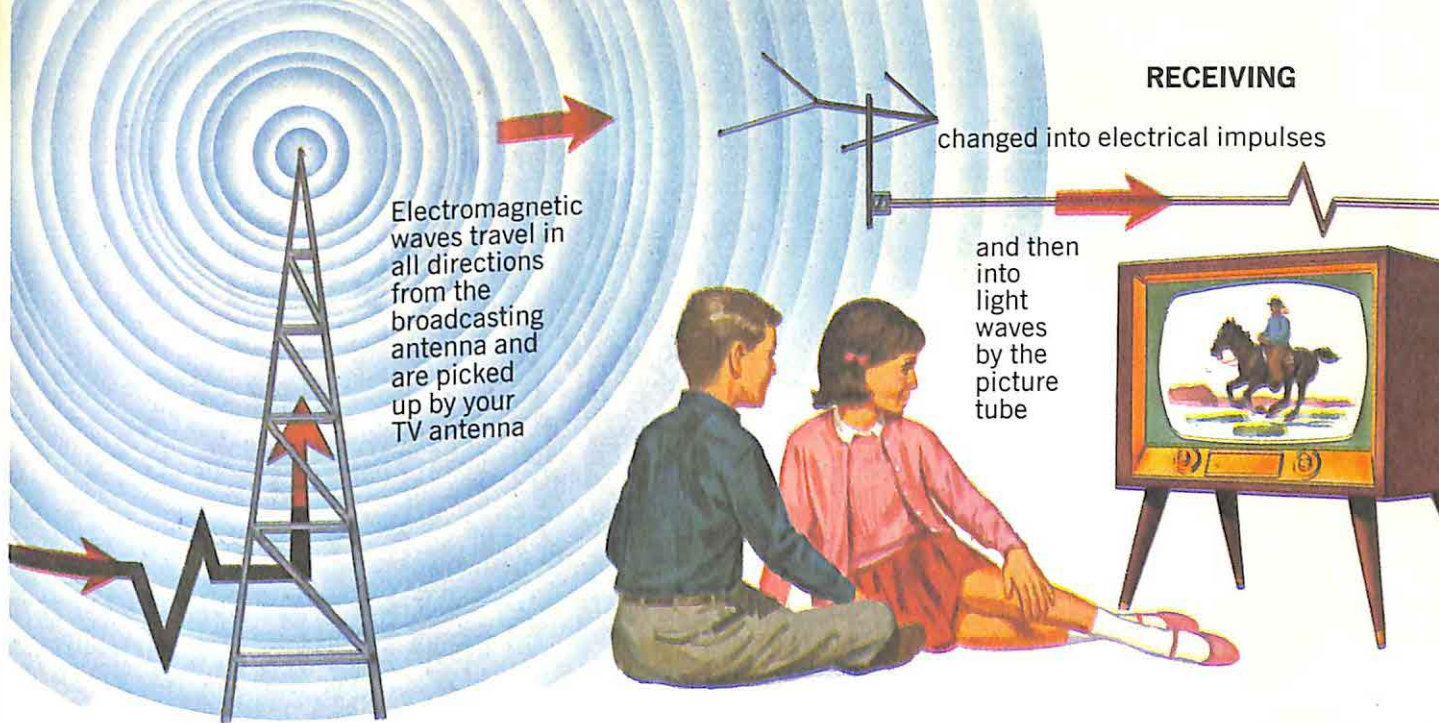
A television set also has a radio receiver built into it which produces the sound to go with the picture.

Saving Life by Wireless

Unless you have a special kind of radio, you do not usually hear police signals. Many police cars now have "radio telephones" that enable them to receive messages from the police station or from other police cars.

Most homes do not yet have radio telephones, but the time may come when they will be very common—in homes, and in most cars. Their use has already saved many lives.

There are other ways in which radio waves can be used to save lives. If a ship is in trouble at sea, an S O S is broadcast by the ship's radio. Warnings of storms, tornadoes, hurricanes, and floods are broadcast by radio. Right now, we are receiving messages from space by means of radio transmitters in satellites. They send us information about the conditions in space—the temperature, the amount of light, and the amount of radiation. Why is such information of value? First, we always need to know more about the world in which we live. Second, astronauts are already going into outer space, and they need



to know as much as possible about the different environments they will encounter.

Transmitting Pictures

How did the pictures of the latest American space flight reach you? How will pictures of the first American to land on the moon reach you? How do pictures of a baseball game and the words of the announcer reach your television set from the ball park? One good way to start to answer questions is to use what you know.

You have learned something of the way the spoken word is transmitted by radio waves. What then can be used to send pictures through space? You will be correct if you say that electromagnetic waves can transmit pictures (patterns of light), as well as words (patterns of sound).

Comparing Radio with Television

In radio transmission, sound vibrations go first into the microphone where they are changed into electric impulses. The resulting radio (electromagnetic) waves travel from the antenna outward in all directions. They are received by the antenna of a radio where they are changed back to electric impulses. The speaker changes these impulses into vibrations which cause sound.

Study the diagram (page 271) which shows the way a radio works. Compare this diagram with the one showing how a television picture is transmitted. ■ How do radio and television compare with each other?

In sending a television picture, light must be used. After all, an object is seen only when light waves are reflected from it.



Let us think of the way a picture, of a horse perhaps, is taken by a camera. ■ The light is reflected from the horse and is focused on the film by the lens of the camera. Since light affects certain sensitive substances on the film, the film is changed chemically by light.

The television camera is also sensitive to light. Study the illustration of a television camera, and, as you do, think of the film in your camera. ■ Notice that the television camera has a screen which is coated with a material that is sensitive to light. When light waves reflected from the horse strike this coating, the pattern of the picture is transferred, by means of a very complicated process, into a pat-

tern of electric impulses. In the television station, the pattern of these impulses is transferred to the electromagnetic waves and is broadcast in all directions from the television station's antenna. Television waves are similar to radio waves but are much shorter in length.

At home, you "tune in" a "channel." Your television set, or receiver, has an antenna that collects the electromagnetic waves. The type of antenna you use depends on how far you are from the transmitter. ● The pattern of these waves is reproduced by electric impulses, which are, in turn, changed into an image on your television screen. The result: you see the horse.

The Story Is Not So Simple

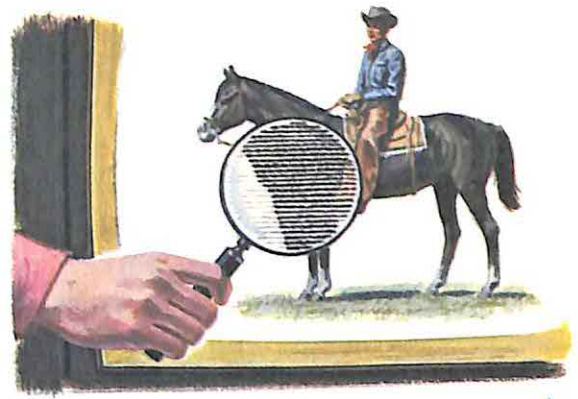
The story of television is not so simple as that given here, however. For instance, the way a picture tube reproduces the picture is quite complicated. Of course, the transmission of color television is even more complicated than the transmission of a black-and-white picture. You will learn more about this amazing story in future science classes.

For a clue now, however, adjust your television picture to get it slightly out of focus. Is it really one solid picture, or is it made up of many small lines, as shown? ▲

The picture is divided into these fine lines before it is transmitted and is then reproduced as a complete picture on your screen.

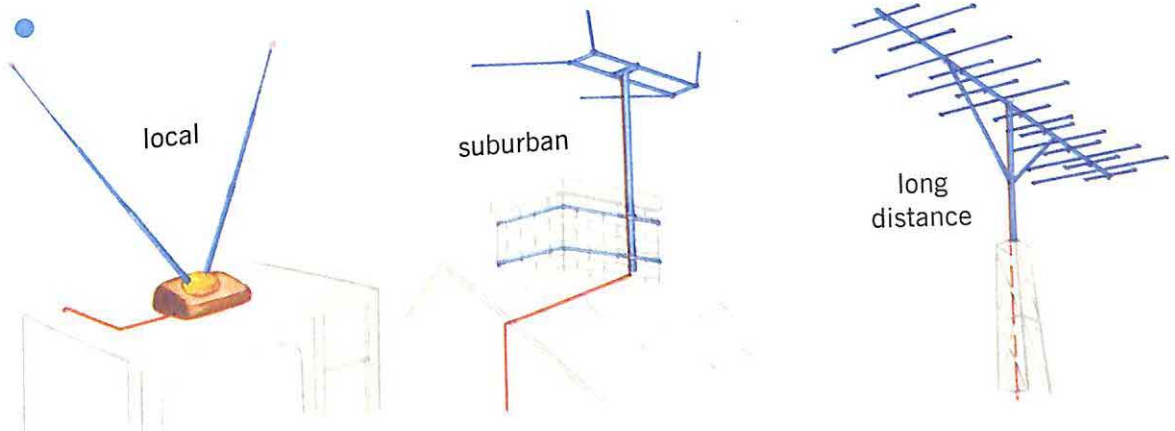
Messages from Space

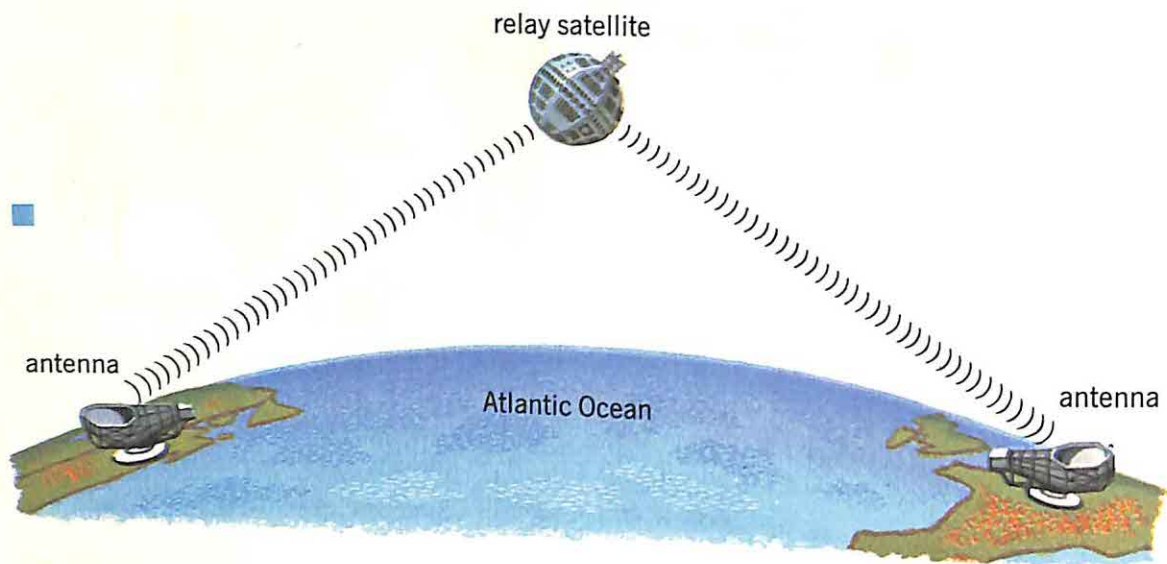
Have you seen movies of the pony express in the early days of the West? Then you know that the riders had stations where they could get fresh horses. At some of the stations, called relay stations, new riders would take



over the job of delivering the mail. Today we use relay stations in space to expand the efficiency of our communications. The relay stations make it possible to transmit certain types of electromagnetic waves over a much greater distance. Someday, many of these relay stations will be permanently placed in space.

Echo I was the first of the communications satellites to be sent out into space. Then came Telstar, which could relay live television broadcasts across the Atlantic. These have been followed by several others. Echo and Telstar are really relay stations; they were the first to be used to bounce





messages back to earth. Since television waves travel only in straight lines, they cannot go around the curve of the earth. The relay satellites receive messages from one point on the earth, and *reflect* the messages to a point on earth a long distance away from the original point of transmission. ■ A relay satellite in space makes it possible, then, to send television pictures much farther.

In addition to sending electromagnetic waves farther on the earth itself, scientists are trying to discover whether the electromagnetic waves that reach us from other stars and planets throughout space can indicate whether there is some kind of life elsewhere in the universe.

Scientists know that there are many kinds of electromagnetic waves traveling through space. The problem has been to collect these and to analyze them to see what conditions caused them to be produced.

Of course, these waves *can* come from stars, meteors, comets, or planets, which are always giving off some kind of waves.

Electromagnetic waves of some type are usually produced whenever energy is released. This can be heat energy, nuclear energy, or light energy. For example, scientists have been able to determine the temperature of Mars by analyzing light waves from that planet.

To find out what kinds of objects in space give off all these waves is one problem, and another is to discover whether any of the waves might be carrying messages.

Is it possible to collect electromagnetic waves coming to us from outer space? Yes.

How are electromagnetic waves from outer space collected? They are collected with the dish-shaped antenna of a radio telescope and also with special relay satellites, such as

Ariel II. The satellite collects all kinds of electromagnetic waves which reach us from outer space and relays them to huge antennas on the ground, as shown in the picture. ●

It would be exciting to find that somewhere out in space there are other planets on which intelligent life exists, and that individuals on one of those planets are trying to send messages to us here on earth. How exciting it would be to try to find out.

Do you think that life on other planets is possible? Is there any available evidence that life exists on other planets? What hypotheses have been developed?

Why not consider this problem for a while? Perhaps you would like to do some research in the library to find what information is available about the possibility of life on other planets. Then perhaps you can do some speculating on your own.



**BEFORE
YOU GO ON**

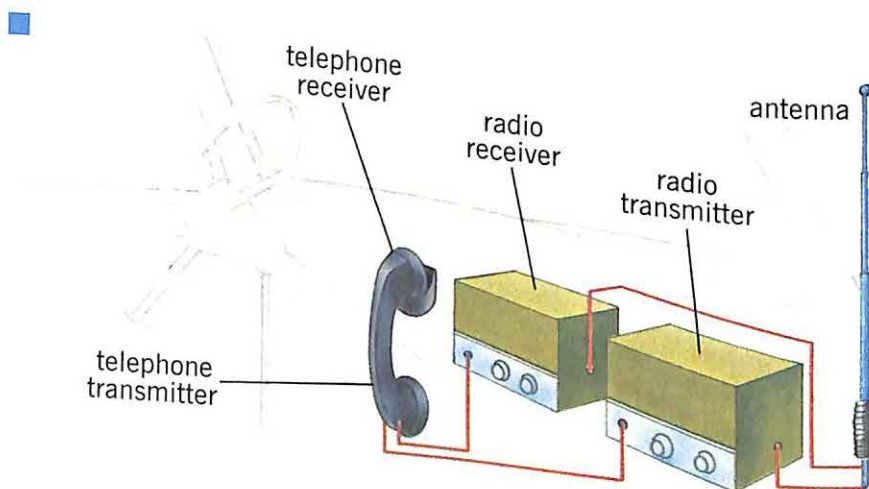
A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Radio waves are
 - a. electromagnetic waves
 - b. sound waves
2. Vibrations of the vocal cords set up
 - a. sound waves
 - b. electromagnetic waves
3. In the radio receiver, electromagnetic waves are first changed into
 - a. electric impulses
 - b. sound waves
4. In the television receiver, the electromagnetic waves are first changed into
 - a. light waves
 - b. electric impulses

B. Write two or more paragraphs on either of these two topics: How a Radio Works; How Television Works.

**USING WHAT
YOU KNOW**

1. Voice patterns can be transmitted by means of the radio, as well as by means of the telephone.
 - a. How is a radio similar to a telephone?
 - b. How is it different?
2. Below is a diagram of a radio telephone. ■ What is the difference between it and an ordinary telephone?



6. The Main Concept: Changing and Transferring Energy

From 93,000,000 miles away, energy from the sun runs your television set. Do you think that this is a ridiculous statement? That there is no evidence for such a statement? If so, follow this energy chain. ●

The sun's energy heats water, which evaporates to form water vapor. The water vapor rises into the atmosphere; and, sooner or later, it cools. As the water vapor cools, it condenses to form clouds from which fall rain, snow, and sleet.

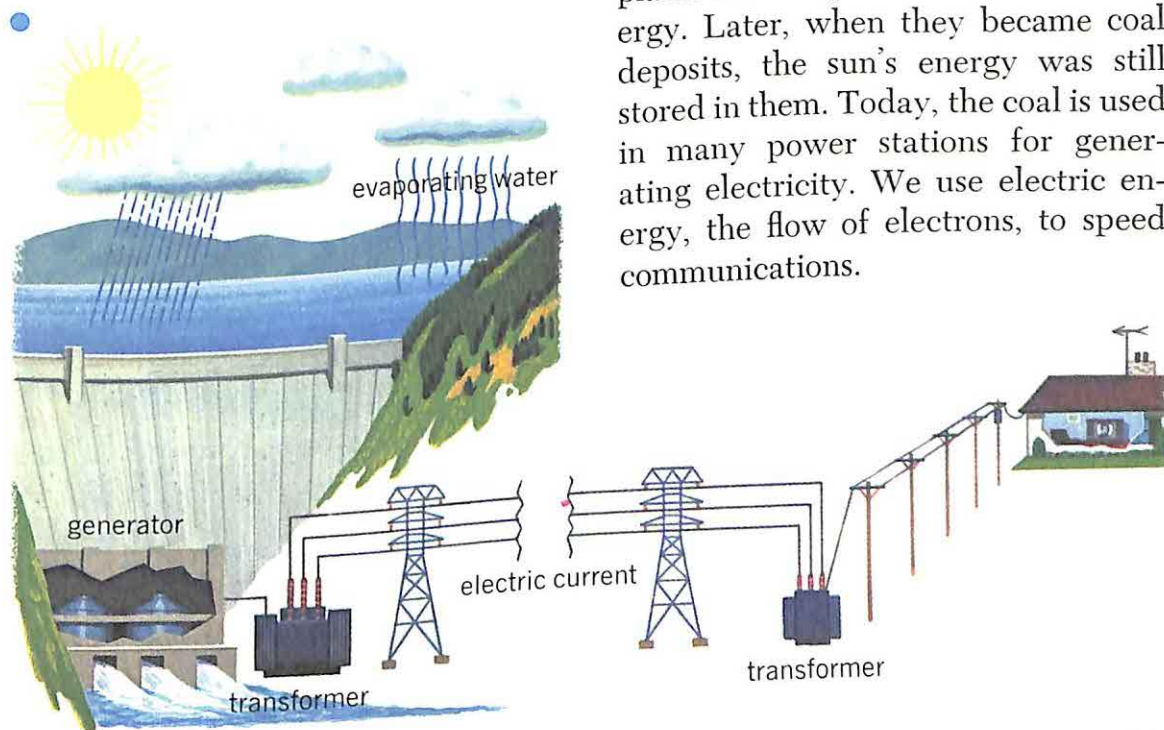
The rain flows into rivers or lakes and may be stored behind dams. At the bottom of a dam, the force of falling water can turn a turbine and

run a generator. The generator produces an electric current, which travels along wires to your house. There it runs the television set and many other appliances.

Even when the turbines are turned by steam, the energy may have come from the sun. Steam comes from boiling water. What supplies the heat to boil the water? It may still be the sun.

Heat must be used to change the water into steam, and the heat required may be supplied by burning coal. Where did the coal come from? It came from ancient plant life, from huge forests buried deep in the earth where pressure and heat turned the plants and trees into coal. The plants used the energy of the sun to make food. The food was then converted into the plant body for growth.

While they were growing, the plants stored up some of the sun's energy. Later, when they became coal deposits, the sun's energy was still stored in them. Today, the coal is used in many power stations for generating electricity. We use electric energy, the flow of electrons, to speed communications.



As long as men could only communicate face to face, their world was very small. When scientists learned how to control electricity, communication became faster. Wherever wires could go, man could communicate with words or codes.

Then came the discovery of electromagnetic waves. Man was no longer limited to the use of wires. Electromagnetic waves travel in all directions at the speed of light.

We can hear a voice from Rome, or Paris, or London, by radio the moment the first word is spoken. Moreover, electromagnetic waves can also be used to send pictures. Not only do we hear the sound of voices or music by radio, but we can also see announcers, or musicians, or actors, on television screens.

These are some of the uses of moving electrons. The world has been made smaller by the use of electro-

magnetic waves, and this is another example of how science and technology, working together, change the world. (See Unit Two.)

Scientists study the *phenomena* of the world—for instance, the phenomenon of moving electrons. On the basis of their study of phenomena, scientists develop concepts. Engineers use the concepts to invent tools and machines to improve man's environment. As a result, we have light bulbs, electric engines, radio, television, telephones, and many other products that would not exist without the combined efforts of science and technology.

This is not the end of the partnership of science and technology, of ideas and tools, however. We are beginning to use not only the outer parts of the atom, its electrons, but also its nucleus. The uses of the atomic nucleus are discussed next in your study of the environment in which you live.

Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts in this unit by doing these problems.

1. Have you ever observed a car pass a tollbooth on a bridge or a highway? Next time you are near a tollbooth, notice the wire that sticks up from the road near the booth. It is long enough to touch the bottom of a car or a truck.
Why is the wire there?

2. What you see in the figure was removed from an electric bell. ■ Will the bell still work? If not, why not?



3. What you see in the figure was removed from the transmitter of a telephone. ● Will the transmitter still work? If not, why not?



4. What you see in the figure was removed from the receiver of a telephone. ▲ Will the receiver still work? If not, why not?

5. Should the motor shown in the illustration work? ◆ If your answer is "yes," why? If your answer is "no," why not?

QUICK TEST

Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this unit.

1. Your table lamp has a wire ending in a plug. When you put this plug into the wall socket, you connect the lamp to a source of

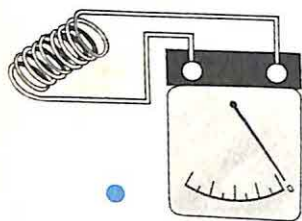
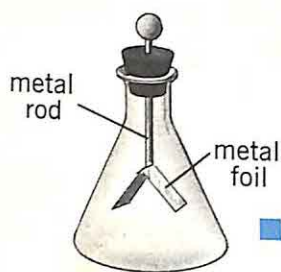
- a. current electricity
- b. static electricity

2. Current electricity moves in a

- a. nucleus
- b. circuit

3. Both current electricity and static electricity consist of

- a. neutrons
- b. electrons



4. The two metal leaves in the jar (called an electroscope) have moved apart, as shown. ■ They are charged with
 - a. like charges
 - b. unlike charges
5. A coil of wire is connected to the meter. ● To make the needle of the meter move, we should move, back and forth in the coil, a
 - a. plastic rod
 - b. magnet
6. When a current passes through a wire, it produces
 - a. static electricity
 - b. magnetic force
7. In radio transmission the pattern of a sound wave is carried by
 - a. electromagnetic waves
 - b. sound waves
8. On a television screen, the picture is reproduced from
 - a. electromagnetic waves
 - b. sound waves
9. When coal or oil is burned to generate electricity, chemical energy is used to produce electric energy. In this process energy is
 - a. created
 - b. transformed
10. In generating electricity, the mechanical energy of falling water can be used to turn the generator. In producing electric energy from mechanical energy, energy is
 - a. destroyed
 - b. transformed
11. When energy is changed from one form to another, work
 - a. must be done
 - b. is not needed

FOR YOUR READING

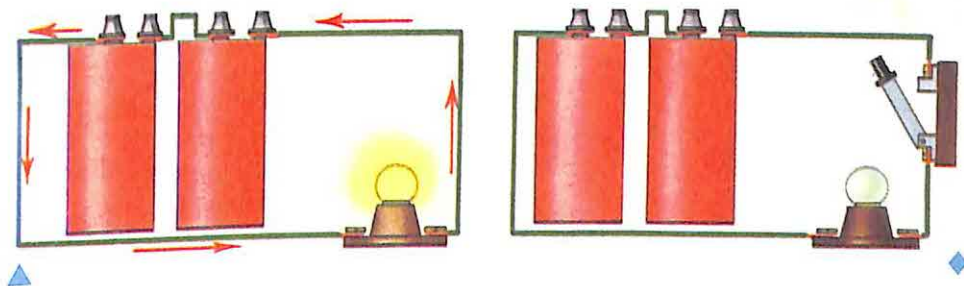
This book is useful for a further study of electricity. Even *before* you go to other books, however, why not examine the section **ON YOUR OWN**, which follows this one.

Experiments with Electricity, by Nelson F. Beeler and Franklyn M. Branley, published by the Thomas Y. Crowell Co., New York, 1949.

ON YOUR OWN

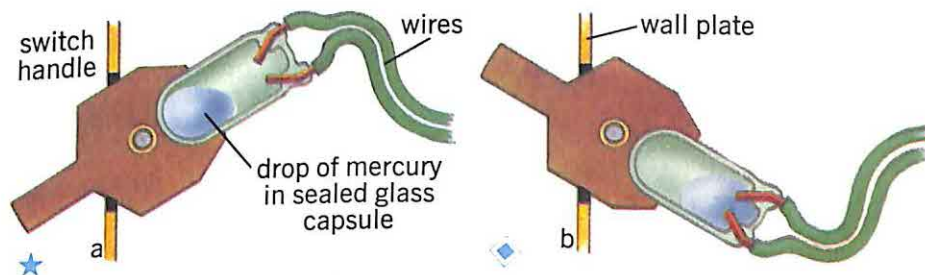
1. An electric circuit is illustrated below. The electricity flows in something like a circle from the dry cells to the lamp. ▲ As long as it does, the bulb lights. In the figure on the right, why is the bulb not lit? ♦

2. Now an open switch is placed in the circuit. ♦ How would you get the bulb to light?



3. Switches may be made of different kinds of metals. One kind is the mercury switch. Since mercury is a liquid metal, it is a good conductor of electricity.

Is the current on when the mercury switch is in position “a” or when it is in position “b”? ★ ♦



IN THE LIBRARY

The following American scientists did work in the field of electricity. What discoveries did they make?

1. Benjamin Franklin
2. Josiah Willard Gibbs
3. Thomas Edison
4. Alexander Graham Bell
5. Lee De Forest
6. Allen B. Du Mont

SUBCONCEPT

Each different atom consists of particles arranged in its own characteristic structure.

Processes emphasized

Development of models
Analysis of data
Hypothesizing
Theorizing
Prediction
Library research

The basic atomic particles are protons with a positive charge, electrons with a negative charge, and neutrons with no charge.

Equipment and Materials

... powdered sulfur
... piece of sulfur

Section 1: INSIDE AN ATOM

The pupils study the arrangement of electrons in levels around a nucleus consisting of neutrons and protons. Modeling of a few atoms helps develop the hidden likenesses and differences inside all atoms.

Introducing the Concept

In Unit Six, the pupils were chiefly concerned with harnessing the energy of electrons; they may not recall or be aware that they were studying the behavior of a part of matter smaller than an atom. You may find it necessary to build again upon their past comprehension. What is matter made of? A number of answers are possible. Pupils are certain to mention elements, compounds, molecules, atoms. Which is the smallest particle of matter we can have that still has the properties of a substance? (A molecule.) Is a molecule the smallest particle of matter? (No. Molecules are built of atoms.) What are atoms built of? Let pupils record their hypotheses without comment at this time.

Have we used any part of the atom in our study so far to get energy? (Yes. We have "rubbed off" electrons and gotten electrical energy.) Do you think we can use any other parts of the atom to get energy? What part? (Some pupils may correctly infer from the use of electrons that a positively charged particle might also be used.) What kind of energy? (NOTE. Pupils will have no difficulty in answering "atomic energy." The term *nuclear energy* is more accurate because the source of energy is the nucleus of the atom. You will gradually wish to shift the thinking of your pupils to this term, as the unit develops.) Before reading of the text, suggest these guide questions:

What are the main particles of an atom? How are they held together in an atom? How are the particles arranged in an atom?

Developing the Concept

The atom and its particles. After you have let pupils read through "A Newer Model of the Atom," it may be well to discuss the paragraphs to reduce misconceptions and clarify concepts. For example, physical division of copper into smaller and smaller particles is not possible to do easily. However, since sulfur is an element, you may first display a piece of sulfur and then some pulverized sulfur. Have we the smallest bit of sulfur we can have? (No. Probably each bit of sulfur powder consists of millions of atoms—perhaps 30 billion side by side would measure less than one-half inch.)

How do we know that there is anything smaller than an atom? (Text pages 286-87 and later work.) What clue did scientists find to a possible new source of energy? The alpha particles mentioned were later discovered to be nuclei of helium atoms given off by radium atoms as they changed to another element, radon. The rays mentioned were later found to be another particle (an electron), and radiations (electromagnetic

waves), a form of energy released by the radioactivity, or decay, of the radium. Matter had changed from one form to another—from radium to radon—and given off energy. This information need not be contributed unless pupils raise the question. An investigation into models of several atoms of relatively simple structure (text page 289) is useful before further reading and discussion.

Atomic structure. Pupils should have little difficulty in inferring that the models are alike in the balance of charges (same number of protons as electrons; that they all have neutrons and protons in the nucleus, and that they are different in the number of particles). Incidentally, more recent models of atoms show the electron as a kind of cloud, rather than a particle, moving about the nucleus; but for the purpose of developing the concept of atomic structure, the Bohr diagrams of atoms are more convenient and more comprehensible until pupils have reached greater maturity. Pupils may also note that the models show electrons arranged in levels around the nucleus. The inner level has only two electrons; the outer level may have from one to eight electrons, but never more than eight. More complex atoms than those shown may have up to 32 electrons in levels between the inner and outer levels. Complex forces keep the number of electrons constant in these levels and also keep them from falling into the nucleus.

The correct filling in of the table (page 290) follows for reference:

	Pro- tons	Elec- trons	Neu- trons		Pro- tons	Elec- trons	Neu- trons
hydrogen	1	1	0	silver	47	47	61
helium	2	2	2	gold	79	79	118
lithium	3	3	4	calcium	20	20	20
carbon	6	6	6	iron	26	26	30
oxygen	8	8	8	phosphorus	15	15	16
nitrogen	7	7	7	uranium	92	92	146
sodium	11	11	12	chlorine	17	17	18
potassium	19	19	20	sulfur	16	16	16

By following the procedure suggested in the textbook, pupils should be able to understand the concept of atomic weight.

Making models. To introduce model making (text page 293) with a class that is slow to comprehend a concept, you may wish to have small groups—two to four pupils—first model hydrogen and helium atoms. Hydrogen does not have a neutron (atomic weight, 1), and helium has two neutrons and two protons (atomic weight, 4). Follow the suggestions in the investigation. Stimulate thinking by comparisons such as: If a nucleus were the size of a tennis ball, the nearest electron would be a mile away. If the atom were a mile across, the nucleus would be the size of a pea. Make note of the more accurate models and draw attention to them. As the pupils consider the difficulty of representing sizes and distances in a model, they will begin to say: "Our models are too small"

The number of particles in an atom determines its structure and its atomic weight.

Pupils reinforce their concept of atomic structure by modeling several atoms.

Equipment and Materials

See text page 293; also the Teacher's Manual for Classroom Laboratory 6.

or "The electrons are too close to the nucleus" or "Our electrons are too big compared with the nucleus." Models are a help in understanding likenesses and differences and in making comparisons. While never more than approximations, accuracy in representation should be encouraged.

Extending the Concept

Reports. The average reader will find *The Story of Atomic Energy*, if you have it on your science reading table or in the school library, a source of information about the leaders in the development of nuclear energy. Suggest selecting one scientist and preparing a report of his work. What problems did he meet? How did he solve them? A more advanced reader will find *The Peaceful Atom* especially useful.

Reviewing the Concept

Before You Go On. 1. b 2. a 3. The top drawing should show 6 protons in the nucleus; the second drawing should be completed by showing 8 electrons outside the nucleus. 4. b 5. b

Using What You Know. 1. Oxygen: 8 protons; nitrogen: 7 neutrons, 7 electrons; chlorine: 17 protons; sodium: 12 neutrons, 11 protons. 2. It would have 10 electrons; it would be neon.

Section 2: SPLITTING THE NUCLEUS

Pupils gain understanding of the tremendous force that holds atoms together and appreciation of the problems of both scientists and technologists in releasing the energy in the nucleus.

Introducing the Concept

Would you like to change lead into gold? Some pupils may recall that this was the concern of alchemists during the Middle Ages. Lead has an atomic weight of about 207 and gold an atomic weight of about 197. From what you learned in the last unit, what would you have to do? (Change the atomic weight.) How could you change the atomic weight? (Get rid of some neutrons and protons.)

What is radioactivity? How can the nucleus of an atom be changed? What would you have to do?

Developing the Concept

More about the nucleus. As the pupils read the section through "Bullets to Split an Atom," encourage the making or inventing of models that describe what happens, and some of the problems. The effect of shooting a marble at a tightly-massed group of marbles, as suggested on text page 294, may be demonstrated as a model of splitting the nucleus of an atom. It does not, however, illustrate how tightly the nuclear particles

(Text pages 292 and 294)

(Text pages 294-302)

SUBCONCEPT

When the nucleus of the atom changes, energy is released.

Processes emphasized

Development of models
Analysis of models
Hypothesizing
Theorizing
Prediction
Library research
Observation

The parts of the atom are tightly bound together; certain parts are electrically charged.

are bound together. Let pupils attempt to pull apart two strong Alnico magnets as a model of the binding force. If tenpins are available from a toy set, let several volunteers demonstrate the difficulty of scoring a "direct hit" with the ball so that all ten of the pins go over. Increase the distance. How does the difficulty increase? Let us now assume that a marble is a neutron and one of the Alnico magnets is the nucleus. Can you bring the marble to either end of the magnet? Now assume that the positive end of one magnet is a proton and the positive end of the other magnet is a nucleus. What is the charge on the nucleus? What is the charge on the proton? (Both positive.) Let volunteers try to bring the positive ends of the magnets together. What happens? Naturally, they repel each other.

If our stack of marbles (nucleus) had a positive charge, what would a positively charged marble shot at it do? Volunteers may try moving the poles of the magnets toward each other at varying speeds. Are the chances better of making the poles touch if the "proton" magnet is moved toward the "nucleus" magnet faster or more slowly? If an electron were used to try to hit the nucleus, what would happen? Pupils have grasped the concept if they respond that the outside electrons on an atom have a negative charge which would repel an electron long before it reached the nucleus, or that the electron might merely add itself to the outer electron level. These models demonstrate some of the questions scientists and technologists had to learn to ask, and then to solve, in order to split the nucleus and release its energy. They had to find a particle that could be used to hit the nucleus; they had to be able to direct it over a great distance (it would be like hitting a BB shot on the 50-yard line of a football field by shooting at it from under the goal posts). They had to give the particle the right speed; and they had to find atoms with nuclei that broke up more easily than others.

Particles for bullets. In 1896 a French scientist, Henri Becquerel, noticed that uranium gave off energy as radiations. In 1898 the Curies isolated radium. Ask why this discovery was so important. (It put scientists on the track of a particle that might be used to alter the nucleus.) What kind of particle is this and what charge does it have? (Alpha particle; positive charge.) How many marbles can you hold in one hand? If you try to hold another marble, what happens? The handful of marbles acts like an unstable atom, and one or more marbles squirt out. Pupils should not infer that radioactivity and nuclear fission are identical processes. Radioactivity is a slow change of an atom of one element into an atom of another, with the emission of a helium nucleus (alpha particle) and radiations. Fission is the splitting of one atom into atoms of two or more different elements, with release of energy, as will be seen in Section 3.

Atomic number. The list of common elements in the table on page 291 may be supplemented by a full periodic table or chart. All of the elements above lead (No. 82) are more or less radioactive. Pupils may enjoy practicing these questions with one another: What happens when

Equipment and Materials

- ... marbles
- ... 2 Alnico magnets
- ... tenpins from a toy set

Radioactive (unstable) atoms emit particles from their nuclei; these particles have energy.

A change in the number of protons in an atom changes the atom into that of another element.

Equipment and Materials

...periodic table or chart of the elements

Energy input is needed to raise the atomic number.

a proton is added to X element? When it is taken away? What happens if an electron is added? An electron taken away? What happens if a neutron is added? These five questions help them see that a change in the atomic number means addition or subtraction of a proton and, therefore, a change in the element. An addition of an electron merely gives the atom a negative charge (electrical potential). Addition of a neutron changes neither the element nor the charge. A perceptive pupil may infer that addition of a neutron changes the atomic weight. (The resulting atom is an isotope of the original element—see page 302.) If you use a full periodic chart or table, the last 11 elements are not found naturally; they have been made by scientists who have succeeded in adding particles to atomic nuclei. They are all radioactive; they all rapidly change to elements with a lower atomic number.

Adding to the nucleus. What is a natural source of nuclear particles? Pupils recall radioactivity of radium. What does radium give off? (Alpha particles and radiations, or rays.) What is an alpha particle? (A helium nucleus.) What must its charge be and why? (Positive; nuclei are positively charged.) The radiations are known as beta particles and gamma rays. It was found that beta particles were electrons moving close to the speed of light, and that gamma radiations were electromagnetic waves and, of course, had no charge. The scientists studying these rays did not know of these characteristics at first. You may wish to supplement the pupil's text by this additional information. The scientists learned of the characteristics by placing a small sample of radium in a hollow lead block with just one tiny hole. They found that the poles of a magnet placed around the stream of particles from the hole attracted the negative particles (beta rays) toward the positive pole and the positive alpha particles toward the negative pole, but that the electromagnetic waves (gamma rays) were undeflected.

Ernest Rutherford, after many experiments, developed a device which directed a stream of particles from radium through a hole in a lead sheet that absorbed all radiation except that going through the hole. Between the hole and a special screen, he placed a sheet of foil. Some of the particles went right through, while others were deflected; but as they hit the screen, flashes were given off which could be counted. With this *scintillation counter*, Rutherford, in 1911, was able to measure the nucleus and find its electric charge. Eight years later he succeeded, by the use of positively charged particles, in changing an element with an atomic number of 7 into an element with an atomic number of 8. Can you tell what the elements were? (Nitrogen and oxygen.) What must he have added to the nitrogen nucleus? (A positively charged proton.) Rutherford had given great energy to a proton, had packed it into a nitrogen nucleus and changed matter from one form to another.

Speeding up particles. It was not until 1932 that James Chadwick discovered the neutron. Until then, scientists had assumed a nucleus of protons having positive charges equal to the number of negative charges

Energy must be put in to increase speed of nuclear particles.

(electrons). As pupils read "Bullets from an 'Atomic Gun'" (pages 297–99), you will wish to review and reinforce concepts from earlier units. The cyclotron, for example, is a kind of machine. Machines convert energy into a force to do work. What work does an accelerator of protons do? It moves protons, particles of matter, around a long circular path. By increasing their speed, it increases the force of a positively charged proton so that it can overcome repulsion by a positively charged nucleus. When work is done, energy must be put in. What supplies the energy to the cyclotron? (Moving electrons.) How is this force multiplied? (By electromagnets.) How do electromagnets speed up atoms? (Attraction and repulsion.) How do they keep the protons in a circular path? (By the same means.) As pupils examine the illustration of the cyclotron on text page 298, encourage their appreciation of the technological problems that had to be met to design and build this type of machine. Some accelerators weigh hundreds of tons.

Extending the Concept

Seeing radiations. Watch, or clock, dials that glow in the dark are excellent for seeing radiations. The paint is mainly zinc sulfide with a trace of radium chloride in it. As the radium decays (loses particles and radiations), the radiations stimulate the zinc sulfide to give out tiny flashes. These can be seen by taking the watch into a dark room and examining it with a glass after the eyes have become dark adapted—about 7 minutes. Pupils doing this investigation at home report their observations.

Radioactive dating of rocks. Uranium is sometimes referred to as a time clock of the universe. Interested students may do research using library references to discover how geologists determine the age of rocks. Others may wish to report on how geologists use the Geiger counter to discover new lodes of uranium ores, or other radioactive substances.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. b 5. a

Using What You Know. 1. The atom at the left would become a form (isotope) of nitrogen; the middle atom an isotope of oxygen; the atom at the right an isotope of fluorine. 2. The nitrogen atom would become an isotope of carbon. 3. Positive; there would be more protons than electrons, and protons have a positive charge.

Section 3: NUCLEAR REACTIONS

Pupils learn that neutrons produced by the radioactive decay of uranium can, under certain conditions, be made to split other nuclei in a chain reaction with the release of tremendous amounts of energy. Applying earlier understanding that energy produces a force, pupils begin to comprehend that controlling the rate of fission provides a steady force for transfer of energy to machines.

Equipment and Materials

... watch or clock with luminous dial
... strong magnifying glass

(Text page 301)

(Text pages 302–07)

SUBCONCEPT

Energy can be released by fission of atomic nuclei; the rate of fission can be controlled.

Processes emphasized

Development of models
Analysis of data
Invention
Library research
Hypothesizing
Theorizing

Equipment and Materials

... about 100 marbles
... rubber bands, or a spring,
for propulsion
... dominoes (optional)

A chain reaction depends on the quantity of uranium which can undergo fission.

Introducing the Concept

In this study, reliance has to be placed on models that appear to produce an effect similar to that which occurs when nuclei fission. Remind the pupils that understanding the concepts of subatomic particles and their application is one more illustration of the ability of man to think, learn, imagine, hypothesize, theorize, and apply his knowledge through invention. It is well not to lose sight of the partnership between scientists and technologists, which has been stressed in the earlier units.

Rutherford's work was principally to find a way to accelerate a particle so that it could be captured by a nucleus of like charge. When Chadwick discovered the neutron in 1932, the concept of the nucleus changed. With at least two particles in the nucleus, something must hold them together; this something must be a form of energy. It was found that the nucleus of the uranium atom, as it decayed radioactively, gave off a neutron and a large amount of energy. Could a way be found to speed up the production of neutrons and could these neutrons be controlled? This was the basic question.

To introduce the concept, we go back to models, using marbles to make up several nuclei. Arrange 7 or 8 groups of 15 marbles, or a dozen groups of 8 marbles. The marbles in each group touch one another, but the groups are an inch or so apart. Shoot a marble (if you can invent a means of strong propulsion with a spring or rubber band, so much the better) so that it strikes the first group. Imagine that it is a neutron with no charge. What do you think will happen? If the model has been carefully arranged, at least one marble from each "nucleus" will hit (split) another "nucleus." Another model you might use is the familiar domino chain reaction.

How can a chain reaction be set up among atomic nuclei? How can its rate be controlled? How can controlled reactions be used?

Developing the Concept

Keeping a chain reaction going. Imagine you have only 10 groups of marbles next to one another when you shoot another marble at one group. As this group splits, a number of the marbles will fly out at the edge and not hit other marbles. If you have 100 groups, many more marbles will be available from the splitting groups to hit other groups. Now imagine that you can have layers of groups one above the other, and that you have 1,000 groups arranged like a box. Can you see how this box would collapse explosively when hit by one marble? Remember that each marble from each group is pushed out and travels at the same speed that the first marble was traveling when it hit the group. This is what happens in an atomic pile, or nuclear reactor. There is enough uranium so that the reaction keeps going. If there is not enough uranium, too many neutrons escape and the reaction stops. If the neutrons do not escape, there is an explosion. The amount of uranium that will produce the desired chain reaction is known as the *critical mass*.

Neutrons, when traveling at the right speed, cause fission. The number of neutrons captured by nuclei controls the rate of fission.

Controlling the chain reaction. As pupils read the pages of the section, they will encounter several problems that can be clarified for them by models and analogies. Some of the following background information may be useful. Scientists found that slowing down the speed at which neutrons are traveling increased the chances of splitting the nucleus. Later, in 1938, two German scientists, Otto Hahn and F. Strassman, discovered that the uranium nucleus absorbed a neutron and then split like a glass marble dropped on a concrete floor. For an instant the two halves lay together and then the fragments flew apart. If the pupils recall that the nucleus has a positive charge, they can infer that the two halves repelled each other. Whatever the binding energy is that holds the nucleus together, absorption of the neutron appeared to disrupt it and convert it to enormous heat energy—the searing heat of nuclear fission and new forms of matter. Shooting in a neutron had caused matter to change form and release energy. While Hahn and Strassman did not realize they had succeeded in splitting the atom, Dr. O. R. Frisch and Dr. Lise Meitner did. They conveyed their findings to Niels Bohr, who immediately came to New York to work with Dr. Enrico Fermi, an Italian scientist then at Columbia University. On December 2, 1942, the first chain reaction in an atomic pile took place under the Stagg Football Stadium at the University of Chicago.

Suppose the neutron used to start a chain reaction is traveling too fast, will the nucleus split? Two analogies and one model may help suggest the answers. If a pool player puts too much speed on the ball, it is likely to knock the ball it hits right out of the pocket. A golfer who hits his ball too hard won't sink his putt, but will make it roll right over the hole. Toy stores have many kinds of boxes with little holes or dents into which BB shot are to be tilted to form a pattern. If there is too much tilt or too much speed, the BB shot will not stay in the dent. The neutron, if it is traveling at the right speed, is "pocketed" by the nucleus, which then splits and sends out other neutrons and radiations as energy.

What was used to slow down neutrons? (Graphite.) How did this work? If you roll a ball against the side of a box and let it bounce against the other sides, it soon slows down. The atoms of carbon in graphite do not absorb neutrons, so a neutron bounces around for a while, until it hits a nucleus at a slower speed. It is absorbed and the nucleus splits.

An automobile would not be much use without a carburetor, would it? It sends just the right amount of gasoline (mixed with air) to the cylinders. To control the explosive release of nuclear energy, just the right number of neutrons are needed. Suppose three neutrons are given off by each uranium atom when it splits. (It does give off several.) If each neutron then hits another nucleus, all the uranium atoms, in almost no time at all, undergo fission. An explosion results. If two of the three neutrons can be absorbed, energy is released from only one nucleus at a time. Fission is controlled. This is the role of the cadmium control rods. Cadmium can absorb neutrons without its nucleus splitting.

The role of the shielding can be deduced from the textbook, but you may wish to compare it with insulation. Some pupils may also ask about uranium-235 and uranium-238. What's the difference? The latter has three more neutrons in its nucleus; it does not fission when it absorbs another neutron; it is 140 times as plentiful as uranium-235. These isotopes of uranium can be separated from one another by physical means, and uranium-235 obtained for use in reactors.

A model for review. In summary of the scientific and technological problems of building a nuclear reactor, encourage groups of pupils to design their own models of a nuclear reactor (text page 306). As each group explains its model, other pupils may act as critics. Such questions might be answered as: What is the atomic fuel? (Uranium-235.) What are the "brakes" to slow down neutrons? What is the "neutron sponge" and why is it needed? What is the shield made of? Why must it be so thick?

Extending the Concept

Modeling a chain reaction. You have used marbles to show a chain reaction. Can you design a model that is three dimensional and demonstrate it? Popping corn, for example, shows the effect. When enough heat has been built up, the grains pop one after another with almost explosive suddenness. Pupils may suggest a pack of firecrackers or match arrangements, but these should not be demonstrated if there are rules against the use of fireworks and fire. The suggestion alone, with an adequate explanation, is evidence of understanding the concept.

Reports. Interested pupils may look up and report on such topics as: The Manhattan Project; new elements from nuclear energy; nuclear power plants; useful applications of nuclear energy; and many other topics that will suggest themselves as a pupil begins to do a bit of library research. This investigation can be related to the next section as well.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a 5. b

Using What You Know. 1. The atomic pile would explode, because the rate of fission could not be controlled. 2. Any person within a few miles of the atomic pile might be killed by nuclear radiation and heat, or his body cells seriously damaged. 3. The reaction in the atomic pile would soon stop; the neutrons would be traveling too fast to be absorbed by the nuclear fuel.

Section 4: USES OF NUCLEAR ENERGY

As pupils see how nuclear energy is used to do the world's work, they become more fully aware of the many types of energy changes that can be used to develop a force and of the many ways a force may be transferred and multiplied.

(Text page 307)

(Text pages 308-14)

SUBCONCEPT

Nuclear energy can be harnessed to machines to develop other forms of energy to do work.

Introducing the Concept

A good way to start thinking is to use the model nuclear reactor in the investigation at the end of the preceding section (text page 306). Ask what familiar form of energy the reactor generates? (Heat.) How do you think this heat can be used to do useful work, such as turning machines or generating electricity? What is the source of the energy in a nuclear reactor? (The nucleus of an atom.) Is this potential or kinetic energy? (Potential.) The text is clear on changes that take place between the splitting of the atom and its use to do work, so the text may be assigned for reading, with attention especially to these questions:

How is nuclear energy changed to other forms? What devices transfer the energy?

Developing the Concept

Energy conversions and transfers. Pupils who have grasped the essential concepts of energy conversion with transfer of the forces produced, should be able to trace the link between the atomic nucleus and electricity with little difficulty. The question and answer style below is a guide to return pupils to the track if they fail to follow the key question: What happens next? Wherever possible, pupils should make their own inferences and analysis with as little direct help as possible.

We have nuclei splitting regularly in a reactor. All is going well. What kind of energy is produced? (Radiant, or heat.) How is this energy transferred? (To a liquid metal, or other substance, in a closed pipe.) On some reactors, such as that at Shippingport, Pennsylvania, water at about 525° F., still liquid because under great pressure, transfers the heat. Where does this superheated liquid go? (To a boiler.) Why? (To transfer the heat energy to change water to steam.) What kind of a change is this? (Physical change.) What does this change do? (As water changes to steam, the force generated by the kinetic energy of moving water molecules is multiplied about 1,700 times.) What does this force do? (Turns a turbine.) What is a turbine? (A machine consisting of a bladed wheel that turns an axle, thus multiplying force.) What does the turbine do to generate electricity? (It turns a coil through a magnetic field, changing mechanical energy into the energy of moving electrons.)

In a way such as this, pupils see that nuclear energy is merely another form of energy attached to machines and devices in a different way to produce a force to do work. If they have kept a chart similar to those on pages T-108 and T-130, they may now compare these charts. Encourage them to devise their own chart of conversions of energy and transfer of forces from nuclear energy to electric energy.

Can we use all the energy from a reactor? Even though the energy in a pound of uranium is about equal to that in a million tons of coal, how much of the nuclear energy do you think we can put to useful work? Encourage pupils to point out where some of the energy is changed to forms we do not wish to use. First, some of the neutrons are absorbed

Processes emphasized

Development of models
Analysis of models
Analysis of data
Reporting
Hypothesizing
Theorizing
Prediction
Library research

Nuclear energy produces great forces.

Nuclear energy has produced useful isotopes.

by the control rods in the reactor. Some of the radiant (heat) energy is used to raise the temperature of the liquid in the closed system leading to the boiler, and some is used to change water to steam. There are losses to friction in mechanical parts. In spite of all these losses to unwanted work, nuclear energy still provides a steady source for doing vast amounts of useful work in a short time. Allow speculation as to why nuclear energy can be used in submarines and ships, but not yet in airplanes and automobiles. What would have to be invented first?

Peaceful uses. No discussion of nuclear energy could be complete without some mention of the terrible potential of nuclear energy for destruction; but vastly more important to man are its potentials for peacetime uses. Radioactive cobalt in the treatment of cancer is mentioned on text page 313. Cobalt is not normally radioactive; it is made so by inserting ordinary cobalt into a nuclear reactor. It absorbs neutrons, becoming a heavier, but unstable, form of cobalt—an isotope of cobalt. It slowly gives up neutrons and radiations. Well over 1,000 radioisotopes (radioactive isotopes) have been made in nuclear reactors. Some decay very rapidly; others take many years. Each has its own special use in therapy, in industry, or in helping scientists learn more about the structure of the atom. One of the great values in nuclear energy is that it has given a tool for improving our understanding of the structure of matter and its relation to energy.

Extending the Concept

Nuclear energy and the Northwest Passage. Ever since the discovery of America, navigators had dreamed of finding a passage to Asia around the top of North America. The nuclear submarine *Nautilus* made this trip for the first time in 1958. Here is a topic for an interesting report.

Carbon and uranium dating. Scientists now know that radioisotopes give off particles and radiations at regular rates, some more slowly than others. Carbon-14 has a half-life of 5,568 years; uranium a half-life of over 45,000,000 years. How is radioactive carbon used to find the age of early civilizations, and uranium the age of the earth's rocks? Research into these and other "atomic clocks" can be fascinating.

Using radioisotopes. There are many uses for radioisotopes. For example, how do they tell us: How thick is cellophane? What happens to oil inside your car? How do drugs work inside a person? How do minerals travel through a plant? Where is there a flaw in a steel beam or an engine part? These and many other uses can be investigated as subjects for reports. Illustrations may be found in technical or scientific magazines, often in the advertisements. Some of the uses, with a brief description, may be displayed on the bulletin board.

New uses for reactors. Among the more interesting uses of nuclear energy is the plan for using it to convert salt water to fresh. Encourage students to investigate plans for water conversion in Israel and in Los Angeles and to report other uses they may read about in current events.

Reviewing the Concept

Before You Go On. Answers are based on the pupil's research.

(Text pages 313–14)

Section 5: THE MAIN CONCEPT: PARTICLES OF MATTER

(Text pages 314–20)

The pupils review the changing concepts of the atom and comprehend that discovery of the divisibility of the atom led to new concepts based on the behavior of subatomic particles.

CONCEPT SUMMARY

This section offers opportunity to review once again the close relationship between the ways of the scientist and the ways of the technologist. The questions in the margin suggest ways in which this partnership can be explored. Pupils should first read the section.

Do we always get concepts from direct evidence? (No. We often learn by indirect evidence.) For example, if you saw three or four different tracks in the snow, how could you tell what kind of an animal had passed by? A Boy Scout in the class may tell his experiences, such as: A large animal would make large tracks; a horse would leave hoof marks, but a bear would leave paw marks; a squirrel would have small prints close together, while a rabbit's larger prints would be farther apart. How would you know that a jet plane had crossed the sky? (Vapor trail, indirect evidence based on past experiences.) If atomic particles could make tracks, would you expect different particles to have different tracks (text page 315)?

A simple home-made cloud chamber can be constructed in the following way: Glue a piece of cotton to the bottom of a gallon jar on the inside. Soak the cotton with alcohol. Place a piece of black cloth over the mouth of the jar and screw the lid on over it. Turn the jar upside down over dry ice. (Do not touch dry ice with bare hands; use kitchen tongs.) Shine light from a slide projector through the jar and place one hand on the inverted bottom. In a few minutes, alcohol vapor condenses as clouds. If you observe carefully and patiently, you will see trails from stray radioactivity. If you can get a bit of radioactive zinc sulfide, the substance painted on luminous watch dials, place it inside the jar and note the much stronger trails.

The answer—neutrons, protons, and electrons—should be expanded. How are they alike? (Neutrons and protons are about the same weight.) How different? (Neutrons: 0 charge; protons: + charge; electrons: - charge; little mass for the electron, great mass for the protons and neutrons; neutrons and protons bound together in nucleus, electrons in motion about the nucleus.)

All particles seem to have energy. Pupils, in review of the concepts, should recognize that a proton can be added to the nucleus, thus chang-

CONCEPTUAL SCHEME

When matter changes from one form to another, the total amount of matter remains unchanged.

UNIT CONCEPT

In nuclear reactions, a loss of matter is a gain in energy; and the sum of the matter and energy remains unchanged.

How can we "see" atomic particles?

What are the three main particles in an atom?

What parts of the atom have energy?

Is there a gain in the total amount of matter and energy when the nucleus of an atom is changed by the addition of a proton or by nuclear fission?

ing its atomic number; that a neutron can be absorbed by the nucleus and induce it to split; and that an electron can be "rubbed off" to develop potential energy (electric charge). All situations release energy.

Discussion of this question may, for the moment, be inconclusive. The pupils will not have had all the evidence until they have completed the final unit of the textbook. However, they may be able to infer that matter has been put in when a proton is accelerated sufficiently to add it to a nucleus and thus change the form of matter, as in Rutherford's changing of nitrogen to oxygen. They may also be able to infer that a neutron added to a uranium nucleus causes it to split into other forms of matter (elements), with the result that energy is released as the new elements are formed. Such inferences can be accepted for the time being. Emphasize the fact that a good scientist is continually testing by new evidence any concept he may form. The nature of concepts is their testability. It would appear on the evidence so far presented that *a loss of matter is a gain in energy, and that the sum of the matter and energy in a nuclear reaction remains the same*. Pupils who approximate this conceptual statement are improving in ability to see relationships between concepts.

(Text pages 316-20)

FIXING THE MAIN CONCEPTS

Testing Yourself. 1. b 2. b 3. Slowing down neutrons, solved by providing a neutron deflector such as graphite. Absorbing neutrons to control reaction rate, such as with cadmium control rods. Providing for transfer of radiation (heat) from reactor to an energy converting device. Shielding to eliminate damage from radiation to persons operating reactor. In addition, technologists had to develop materials that would stand up under great heat and large forces generated. Other problems may be mentioned whose solutions can be accepted if supported by the text explanations. 4. The one at the left; protons and electrons normally are equal. 5. The one at the right; protons and electrons are equal in number. 6. It will have 11 protons and 12 neutrons in its nucleus and 11 electrons around the nucleus. (Atomic number = number of protons; atomic weight = protons + neutrons.)

Quick Test. 1. Table completed as follows:

	Protons	Electrons	Neutrons
Oxygen	8	8	8
Nitrogen	7	7	7
Sulfur	16	16	16
Aluminum	13	13	14
Copper	29	29	35
Iron	26	26	30
Uranium	92	92	146

2. Pupil's choice. 3. Chlorine. 4. Magnesium. 5. Change *b* to An electron is *lighter* than a proton, or transpose electron and proton in the printed sentence; *d* to In an atom, the number of electrons is equal to the number of protons; *e* to In an atomic pile, or reactor, fission takes place; *f* to In the sun, fusion is the source of energy.

A CONCEPT OF MASS-ENERGY: A NEW VIEW

In this second New View pupils begin to appreciate that all the energy conversions and transfers they have studied can be summarized in a larger concept of the conservation of matter and energy; that is, in all mass-energy relationships, conversions of energy or changes in matter result in neither gain nor loss in the total amount of matter and energy.

TEACHING SUGGESTIONS

Throughout *Concepts in Science 6* pupils have been noting likenesses and differences. It may be well to review some of the basic likenesses. For example, pupils should be able to cite the obvious likenesses that all the living and nonliving things mentioned in the first paragraph consist of matter. Like peeling the layers from an onion, they may proceed in answer to the repeated question "How else?" to note that matter consists of elements and compounds whose properties are determined by their molecules; that molecules are made up of atoms, which are the building blocks of all matter; and that atoms, in turn, consist of protons, neutrons, and electrons arranged in certain ways. This arrangement determines the mass of an atom, which is represented by its atomic weight.

If you wish to bring out differences in matter, you may wish to have pupils review those between elements (made of one kind of atom) and compounds (more than one kind of atom), and between stable and unstable atoms, to lay the groundwork for discussion of changes in matter.

Several changes may be brought out by the question: What physical changes can matter undergo? The obvious ones of being torn, crushed, or molded—a change of shape or form; then the less obvious, such as dissolving, change of state, which is a change in the kinetic energy of the molecules of a substance, or a change in position, which may give potential energy to a substance. Raising a weight to a height gives it potential energy; so does the transfer of an electron by friction.

What happens in a chemical change? Pupils may cite illustrations of changes in properties, as well as formation of compounds (synthesis) or separations of compounds into elements (decomposition). How can we show that there has been neither gain nor loss of matter in a chemical change? (No change in total weight; that is, no change in mass.)

What other kind of change in matter is possible? Of course pupils recall nuclear changes from the unit they have just completed. Do you think any matter has been lost? Has any energy been gained? Even after their just-completed study, pupils are likely to be divided on this question. Depending on whether you think your pupils are ready to understand a simple mathematical-diagrammatic presentation, you may wish to reproduce the following diagram, showing a loss in mass in the splitting of the uranium atom. The uranium mass of 235 is seen to give two atoms of the uranium atom. The uranium mass of 235 is seen to give two atoms with a combined mass of 233, and there is a loss in weight (mass) evi-

(Text pages 321-23)

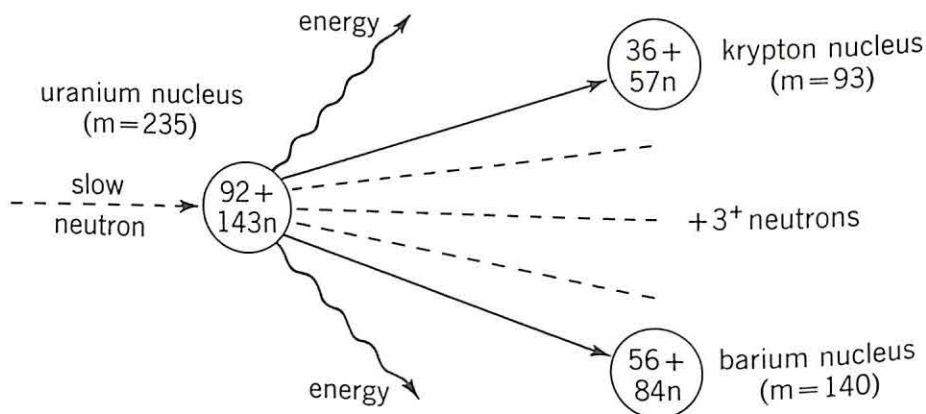
CONCEPT RELATIONSHIPS

In all mass-energy relationships, the sum of the amounts of matter and energy involved remains unchanged.

There are hidden likenesses in matter.

Matter can undergo change.

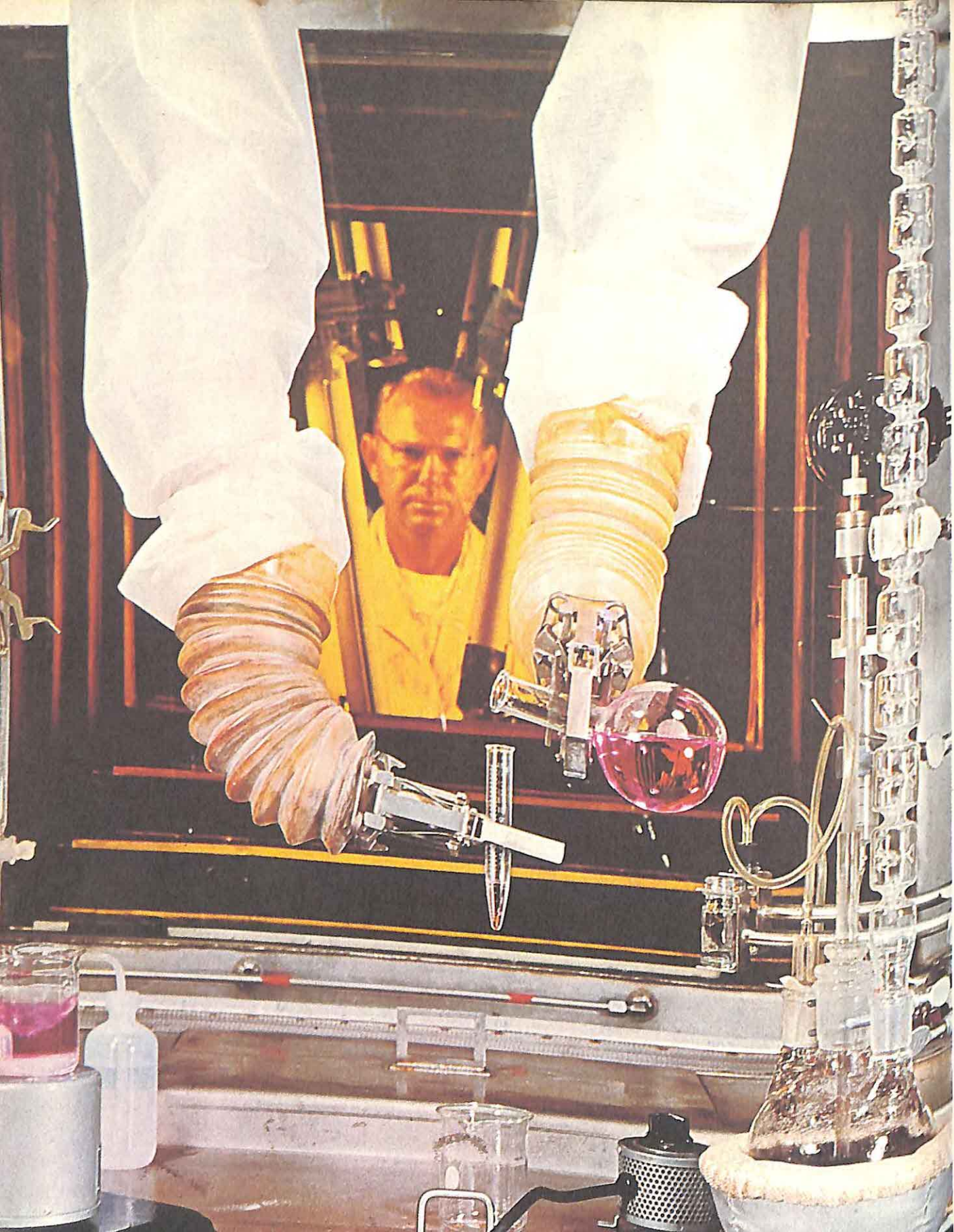
dent in the fission reaction. (For fusion reaction of hydrogen to helium, see pages T-181-82.)



In a nuclear reaction, matter lost equals energy gained.

Now you are ready to explain Einstein's famous equation $E = mc^2$. (For your information, E is expressed in ergs, a very small energy unit, m is expressed in grams, and c in centimeters per second. So the number of ergs produced by a mass of 1 gram would equal $1 \times 300,000,000 \times 300,000,000$. In the English system of measurement, 1 foot-pound is equal to 13,560,000 ergs.) Even without these figures, a pupil can readily see the tremendous amount of energy involved in the conversion of a small mass. Scientists have been able to calculate the observed amount of energy resulting from nuclear reactions. This amount is almost identical with figures resulting from Einstein's formula. With most pupils, this mere statement of confirmation by authorities should convince them of the validity of the conceptual statement in the final paragraphs (in italics) on text page 323.

TEACHER'S NOTES



UNIT SEVEN

MATTER INTO ENERGY

The discovery of atomic particles and the power they contain is one of the new pages in the history of mankind. Left free, this power brings destruction and death, but modern technology enables man to set up protective measures against harmful influences. For example: If you worked in an atomic energy installation, you would carry your own pen-sized radiation monitor in your pocket. When the radiation level gets "hot," the monitor flashes its neon bulb and buzzes a warning tone.

The picture on the opposite page is another example. It shows a device for extending the reach and power of the human hand. Such devices have been developed for very specialized purposes. The one shown is used to handle radioactive materials inside a nuclear reactor and to perform operations in a "hot chemistry" laboratory. In fact, the need for handling radioactive materials by remote control has been mainly responsible for the invention and design of artificial manipulators.

In the world of atomic particles, in a few hundred-thousandths of a second, a frightening quantity of energy can be released. In a nuclear reactor this energy is controlled. In an atomic bomb it is not. Where does the energy come from?

1. Inside an Atom

Before the time of Marie and Pierre Curie, atoms were believed to be the smallest particles of matter, much too small to be seen. It was thought that they were *invisible* and *indivisible*.

The idea that the atom was indivisible was held for a long time. This idea dates back to the Greeks, in particular, to Leucippus and his pupil Democritus, who lived about 400 B.C. Their ideas were purely imaginary and not based on investigation.

Here is what they believed: Take a piece of a substance, such as copper. Cut it in half, then in half again, in half again, and in half again. ■ If you continue this “cutting in half,” the theory was, and still is, that you would finally have the tiniest piece of copper that could exist and still be copper. This would be an *atom* of copper. The atom of copper was considered to be invisible and indivisible. This was thought to be true of the atoms of substances, such as copper, iron, sulfur, zinc, oxygen, carbon, and all of the other elements.

The atom seemed to be the smallest particle of which matter was made.

Much later, John Dalton (who lived from 1766 to 1844) did experiments which seemed to strengthen this idea. To Dalton, too, atoms were like tiny spheres, solid and indivisible. ● They seemed to act as wholes, that is, they could not be divided. This seemed true of all atoms.

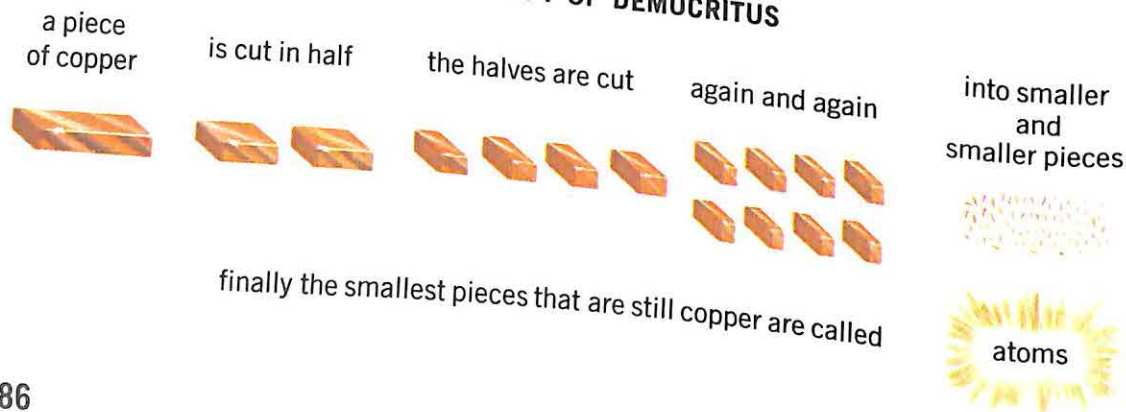
Today, we still hold that an atom is the smallest part of copper that can exist and still be copper; but the atom is no longer considered to be the smallest particle of which matter is made. That atom of copper is itself made of something else. Now we know that atoms can be divided.

The Curies discovered that this was true of radium atoms, at least. Their important discovery gave scientists a new idea, or concept, of the atom and with that, a new concept of matter.

Radium—And a New Concept of Matter

As the Curies worked to get a supply of pure radium, they found that this particular element was giving off

■ THE CONCEPT OF DEMOCRITUS



energy in the form of *rays*. Careful experiments showed that one of these so-called “rays” was really made up of particles. These tiny particles, later called **alpha particles**, were found to be very small—much smaller than a radium atom. In other words, it was found that atoms of radium were *not* solid spheres at all. They were not indivisible. Radium atoms gave off smaller particles! ▲ Therefore the idea evolved that perhaps some atoms, or even all kinds of atoms, might consist of even smaller particles.

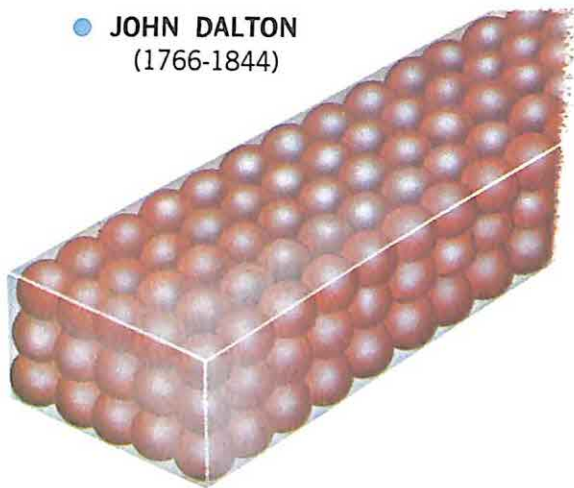
Soon other scientists began to discover alpha particles, particularly when they worked with elements such as radium and uranium. Elements that give off particles spontaneously are called **radioactive** (rā'dē-ō-ak'tiv). They give off energy as well as particles. Notice that the word *radioactive* relates especially to the word *radium*; but uranium was found to be radioactive also.

Experiments with atoms of other elements showed that even though they were not radioactive, they too were made up of smaller particles. Such scientists as Ernest Rutherford (New Zealand) and Niels Bohr (Denmark) showed that *all* atoms were made up of particles. Bohr gave us a new “model” of the atom, showing the atom as made of smaller particles.

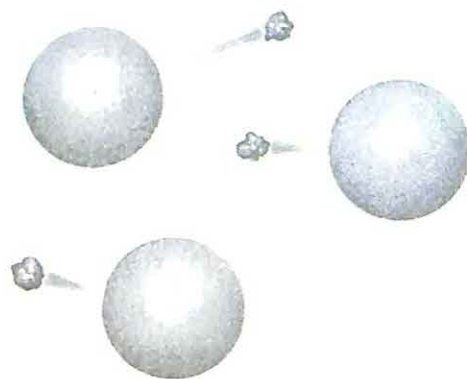
A Newer Model of the Atom

The drawing of the carbon atom on this page shows the kind of model made by Niels Bohr. ♦ Atoms of all

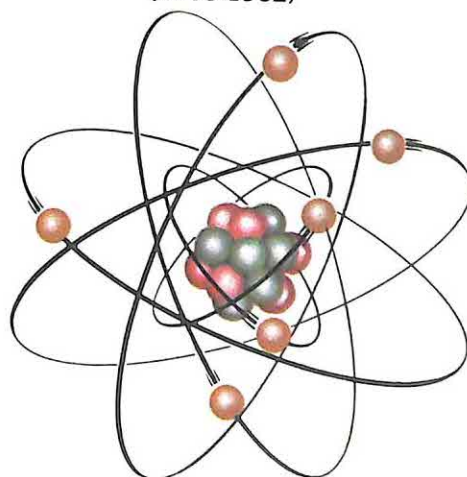
● JOHN DALTON
(1766-1844)

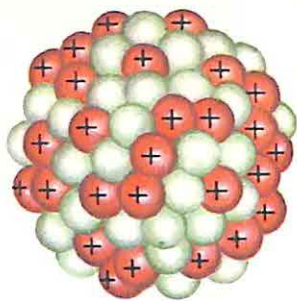


▲ MARIE CURIE
(1867-1934)



♦ NIELS BOHR
(1885-1962)





the elements can be modeled in the same manner. Although each of the atoms is different from every other, they all contain the same kinds of particles.

Now investigate the models of atoms on the opposite page. See what is similar, and also what is different, about the four atoms.

Removing Particles from an Atom

Electrons are tiny particles with *negative* (—) electric charges. Suppose the electrons were removed from the atom of lithium pictured on this page. ■ What would be left? The *nucleus* of the lithium atom (with its **protons** and **neutrons**) would be left.

The symbols (+, —, n) on the model stand for the electric charge of

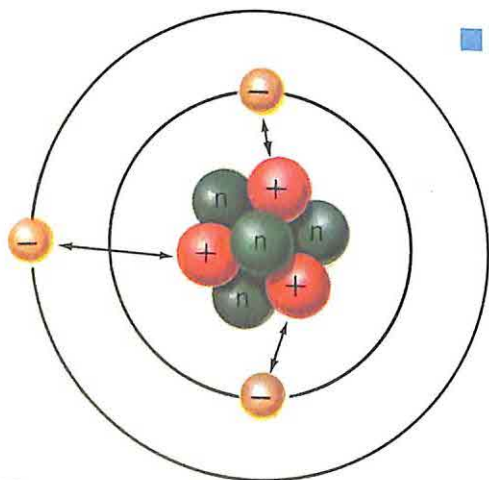
the particle. The protons in the nucleus have a positive (+) charge of electricity. The neutrons (n) in the nucleus have no charge; they are neither positive nor negative, but are neutral. Although the nucleus of an atom consists of neutrons and protons, the nucleus has a positive charge because of the protons. If any of the electrons of an atom are removed, and only the nucleus is left, the atom will have a positive charge. ● Now it is easy to understand why a substance was left with a positive charge when electrons were “rubbed off,” as shown in Unit Six.

Suppose no electrons are removed from an atom. What charge would the atom have?

Study again the diagrams of the atoms of carbon, oxygen, nitrogen, and iron. How many electrons and how many protons does each of the atoms have?

To have a positive charge, an atom must have more protons than electrons. To have a negative charge, an atom must have more electrons than protons. The positive (+) charge of one proton and the negative (—) charge of one electron neutralize each other.

Each kind of atom normally has an equal number of protons and electrons. Check the diagram to see if this is correct. In an atom, the positive charge of each proton balances the equal but opposite negative charge of each electron. The charge, then, of an atom is neutral.



AN INVESTIGATION into Models of Atoms

Needed: physical models as well as diagram models of atoms

Here are models of four atoms drawn flattened out to give you a clearer idea of the number and kinds of particles they contain. The models are of carbon, oxygen, nitrogen, and iron. ■

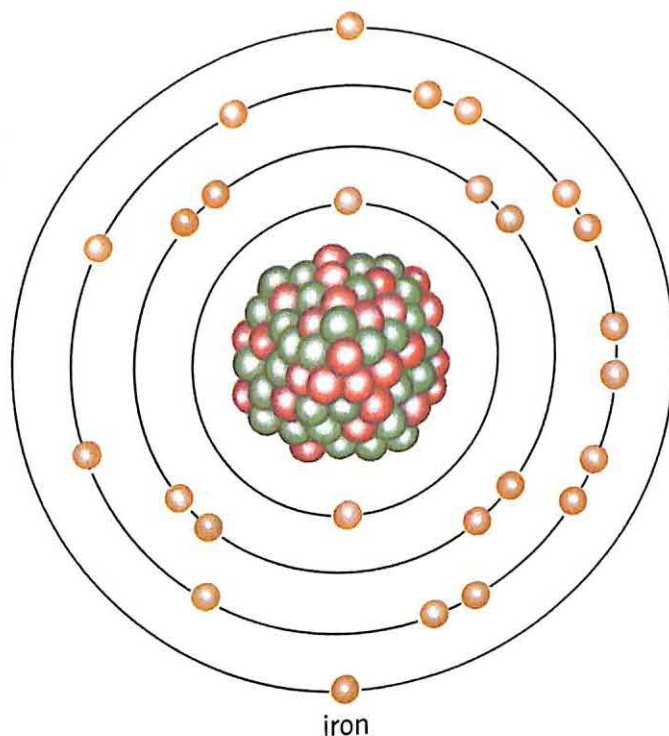
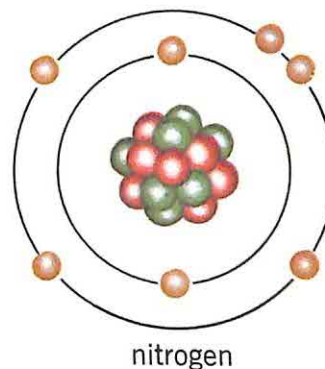
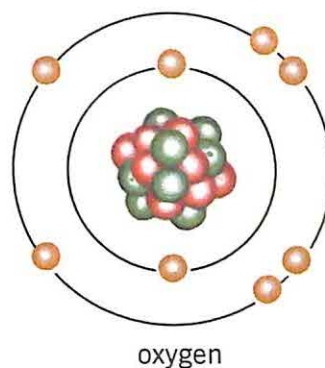
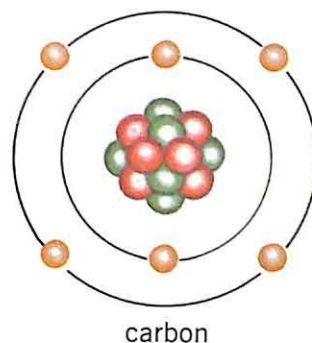
Three kinds of particles are shown. The neutrons are green, the protons red, the electrons yellow.

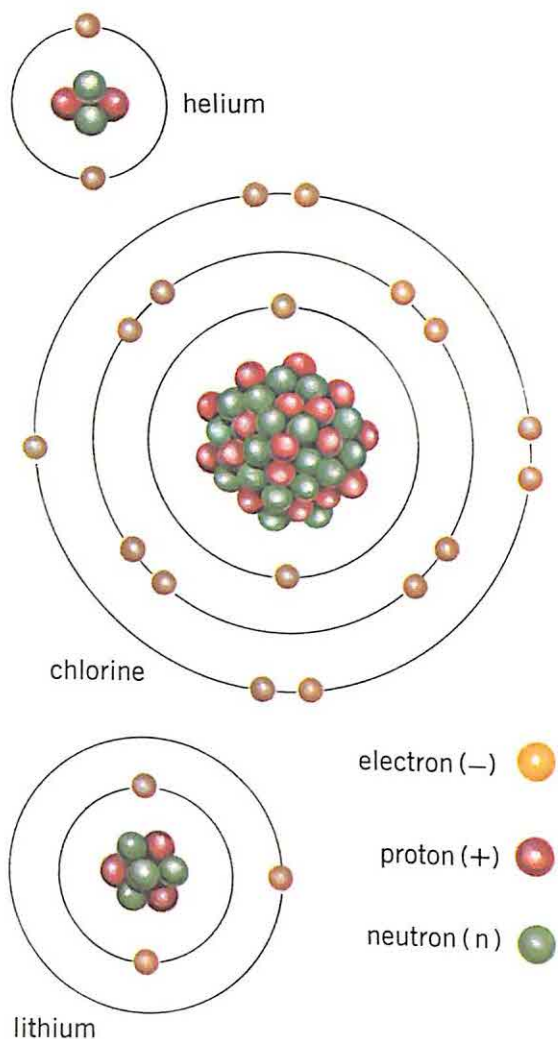
Where are the protons and neutrons located in an atom?

Where are the electrons located?

In what ways are these atoms different from each other? similar?

- neutron (n)
- proton (+)
- electron (—)





Now look at the diagrams of three other atoms—helium, chlorine, and lithium. ■ Try to find the number of protons and electrons in each atom. How many do you find in each of these three atoms?

The Structure of an Atom

Complete the table to show the atomic structure of some familiar elements. ● Copy the table on a separate piece of paper and fill in the numbers of protons and electrons

which are missing from each of the atoms. Remember that all of the atoms are *neutral*. For the moment, however, do not fill in the number of neutrons.

Were you able to fill in the table properly? All normal atoms have equal numbers of protons and electrons. Except for the lightest-weight hydrogen atom, all atoms have neutrons as well. Neutrons have no electric charge. An atom has, therefore, equal numbers of (+) and (−) charges.

Is there any way of determining the number of neutrons in an atom? Study the table of common elements on the opposite page and then try to determine a method for finding the number of neutrons in an atom. ▲ Try to determine this before you read ahead. If you find it difficult, go on to the next page.

	Protons	Electrons	Neutrons
hydrogen	1		
helium			
lithium			
carbon			
oxygen			
nitrogen			
sodium		11	
potassium	19		
silver	47		
gold		79	
calcium	20	20	
iron			
phosphorus		15	
uranium	92	92	
chlorine			
sulfur		16	

NAME OF ELEMENT	APPROXIMATE ATOMIC WEIGHT	NUMBER OF PROTONS (ATOMIC NUMBER)
aluminum	27	13
antimony	122	51
argon	40	18
arsenic	75	33
barium	137	56
beryllium	9	4
bismuth	209	83
boron	11	5
bromine	80	35
cadmium	112	48
calcium	40	20
carbon	12	6
cesium	133	55
chlorine	35	17
chromium	52	24
cobalt	59	27
copper	64	29
fluorine	19	9
germanium	73	32
gold	197	79
helium	4	2
hydrogen	1	1
iodine	127	53
iron	56	26
krypton	84	36
lead	207	82
lithium	7	3
magnesium	24	12
manganese	55	25
mercury	201	80
neon	20	10
nickel	59	28
nitrogen	14	7
oxygen	16	8
palladium	106	46
phosphorus	31	15
platinum	195	78
potassium	39	19
radium	226	88
radon	222	86
rubidium	85	37
selenium	79	34
silicon	28	14
silver	108	47
sodium	23	11
strontium	88	38
sulfur	32	16
tin	119	50
titanium	48	22
tungsten	184	74
uranium	238	92
xenon	131	54
zinc	65	30
zirconium	91	40

Once you know the atomic weight of an atom and the number of protons in an atom, you can determine the number of neutrons. Here is the formula:

$$\text{neutrons} + \text{protons} = \text{atomic weight}$$

The atomic weight given in the table is accurate enough to help you compare the weights of the different atoms. The atomic weight does not include the weight of the electrons. Electrons do not seriously affect the weight of the atom, because they are so very light. It takes 1,836 electrons to equal the weight of 1 proton.

Now use the table of atomic weights and see if you can determine the number of neutrons for each of the atoms listed on page 290.

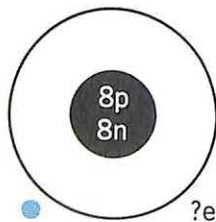
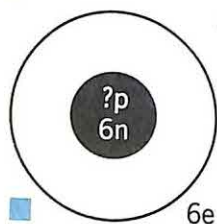
A Look Ahead

Now that you know what is inside an atom, let us split one kind of atom to see what happens. What happens when the nuclei (plural of nucleus) of uranium atoms are split?

Before going ahead, fix the structure of an atom more clearly in your mind. Make your own models of atoms as in the investigation on the opposite page.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.



1. An atom has 11 protons in its nucleus. Outside its nucleus, there are
 - a. 22 electrons
 - b. 11 electrons
2. The atom mentioned in 1 has an atomic weight of 23. It has in its nucleus
 - a. 12 neutrons
 - b. 11 neutrons
3. In your notebook finish the drawings of the two "models" of atoms shown in the margin. ■ ●
4. The electric charge of a single atom is usually
 - a. positive
 - b. neutral
5. The belief that atoms are indivisible was held by
 - a. Bohr
 - b. Dalton

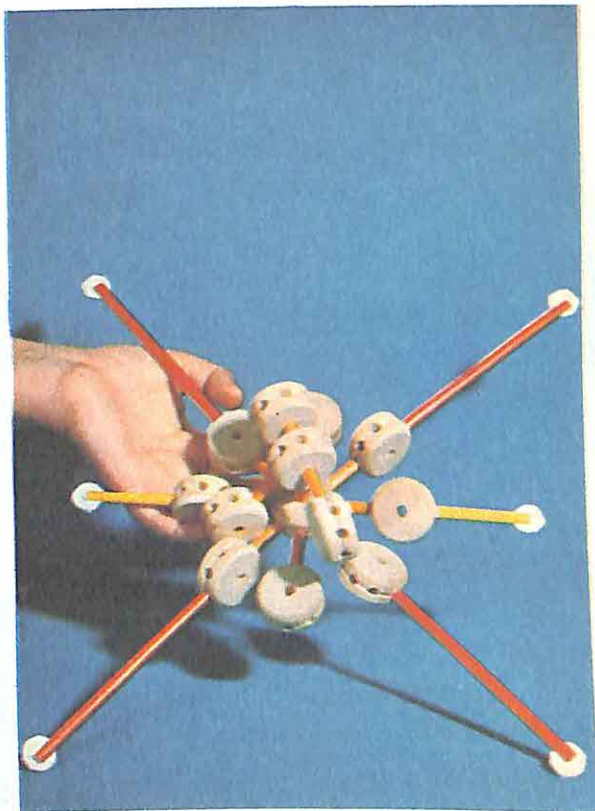
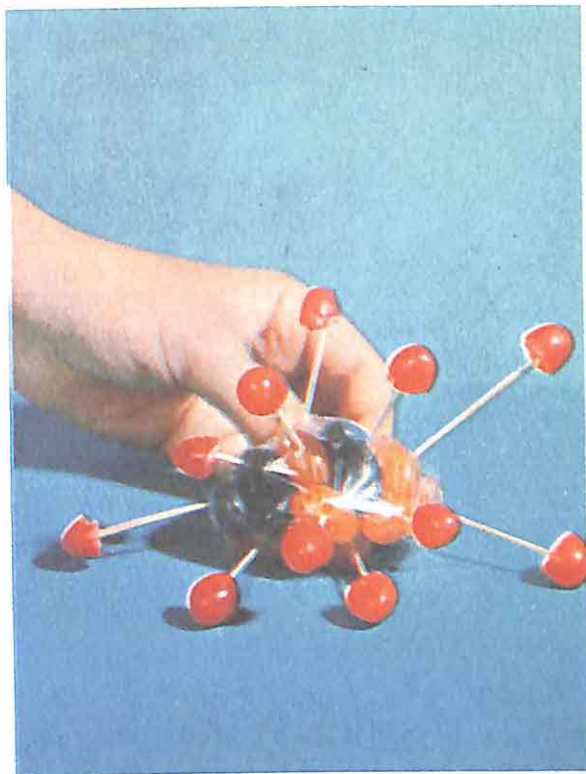
B. Write a paragraph or two on this topic: A Model of the Atom—Today.

MAKING MODELS: The Atom

Needed: materials from which to invent and construct models of sodium, carbon, or oxygen atoms

Only one clue is needed at this time. Notice in the atom models here, and on earlier pages, that electrons revolve around the nucleus on different shells. In the oxygen atom, the shell nearest the nucleus has only two electrons. ■

Invent your own model. ■ ● ▲ What material will you use for the nucleus: clay, perhaps? for the electrons: beads, perhaps? Can you think of a way to make the electrons actually revolve?



USING WHAT YOU KNOW

1. Copy the following table in your notebook and try to complete it. ■

Element	Atomic weight	Number of neutrons	Number of protons	Number of electrons
oxygen	16	8		8
nitrogen	14		7	
chlorine	35	18		17
sodium	23			11

2. In your notebook, draw a model of an atom with 10 neutrons and 10 protons. How many electrons would it have? What is the name of the element?

ON YOUR OWN

One of the great scientists who did much to discover the structure of the atom was Ernest Rutherford, a British scientist. Perhaps you will want to do research in the library to find out more about him.

2. Splitting the Nucleus

When scientists use the phrase “to split the atom,” they really mean “to split the nucleus.” Splitting of the nucleus of an atom such as the uranium atom is called **fission** (fish’ən). What happens when the nucleus of an atom undergoes fission?

Bullets to Split an Atom

Let us make a model of an atomic nucleus, using a collection of marbles. Arrange the marbles as shown in the illustration. Now, how can we split up this model of an atomic nucleus? We can shoot a single marble

into its midst and scatter the marbles in all directions. ●

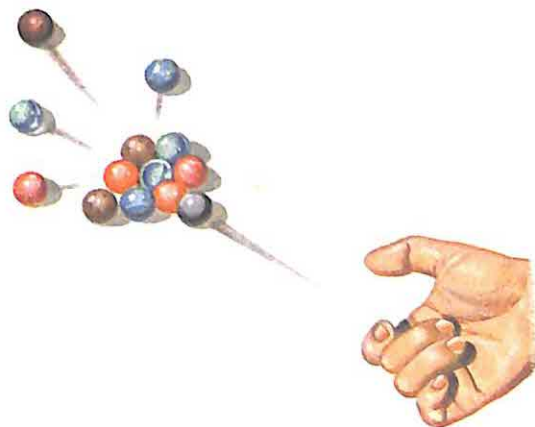
This model gives you the general idea behind the splitting of atomic nuclei. An entire nucleus is very small; but the protons and neutrons are smaller still. Exactly what force binds the protons and the neutrons tightly together in the nucleus is not known; but it is known that tremendous energy is required to separate them.

If the marbles were glued together into a spherical shape, the single marble would have to be hurled with tremendous force to break them apart. What could be used as an atomic “bullet” to be hurled at the target, the

atomic nucleus? Moreover, how could this bullet be given enough force to split a nucleus?

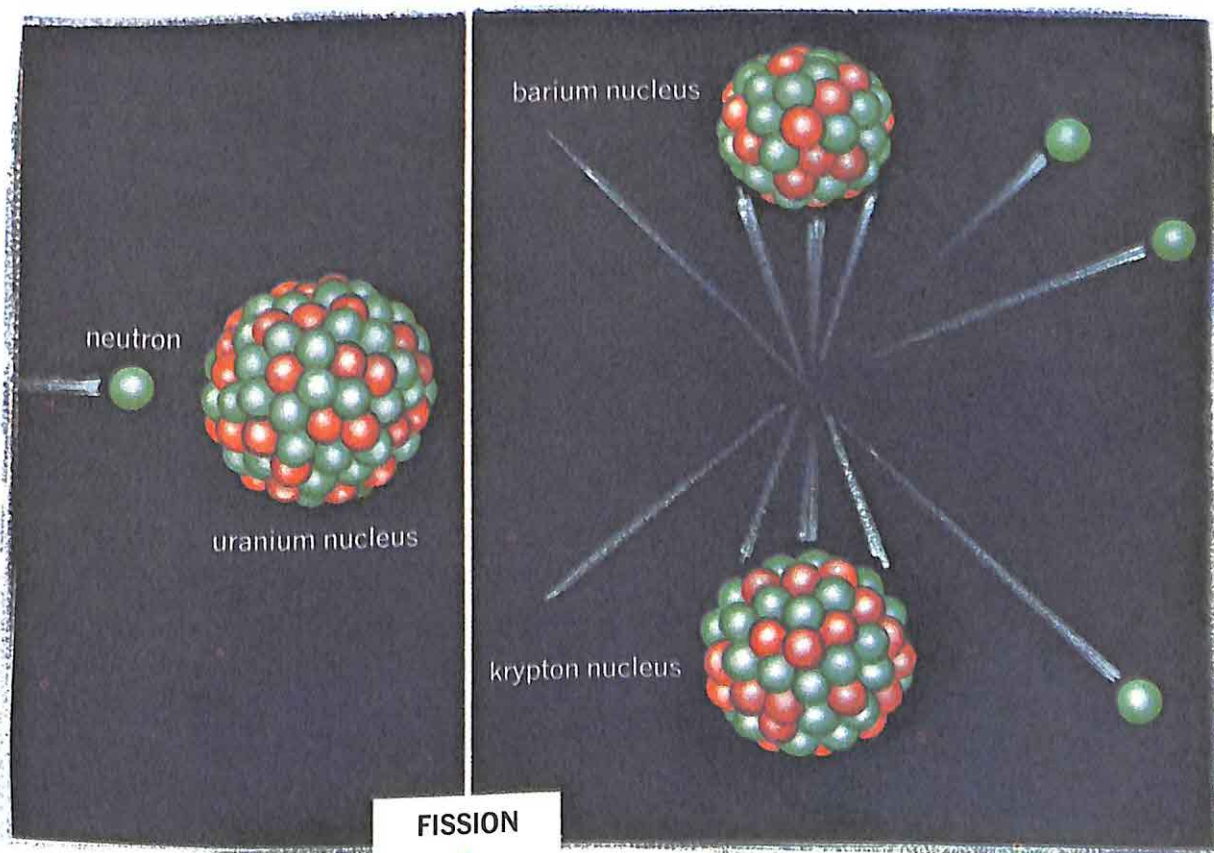
Scientists have found that a neutron, the tiny particle with no electric charge found in the nucleus, can be used to split atoms. ▲ Certain unstable atoms can be made to give up neutrons from their nuclei. These neutrons can be shot into the target nuclei of other large atoms and cause them to split apart into several pieces. ▲

Scientists have also found that certain nuclei, the nuclei of some of the heavier atoms, are easier to split. For instance, the nuclei of uranium atoms break apart much more easily than the nuclei of most other atoms. You

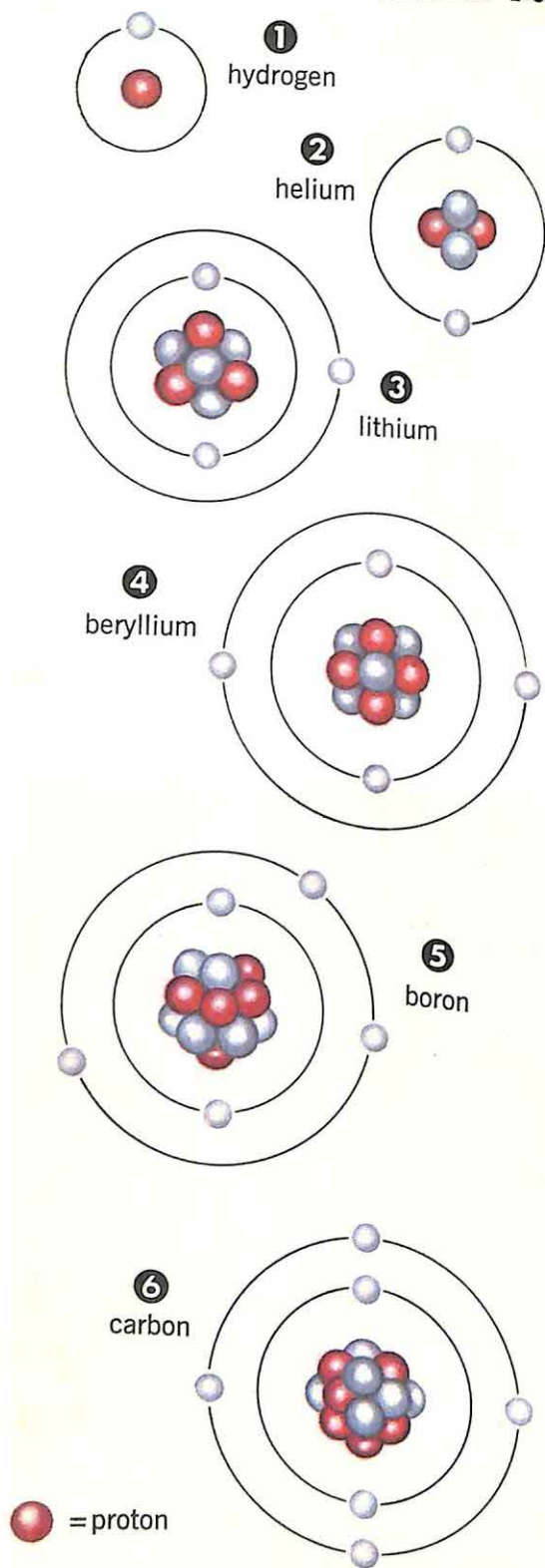


can see from the table on page 293 that the uranium atom is a very heavy atom. How many protons does it have in its nucleus?

Neutron bullets have been used to split uranium atoms. The uranium nuclei undergo fission. Each nucleus



■ ATOMS WITH ATOMIC NUMBERS 1-6



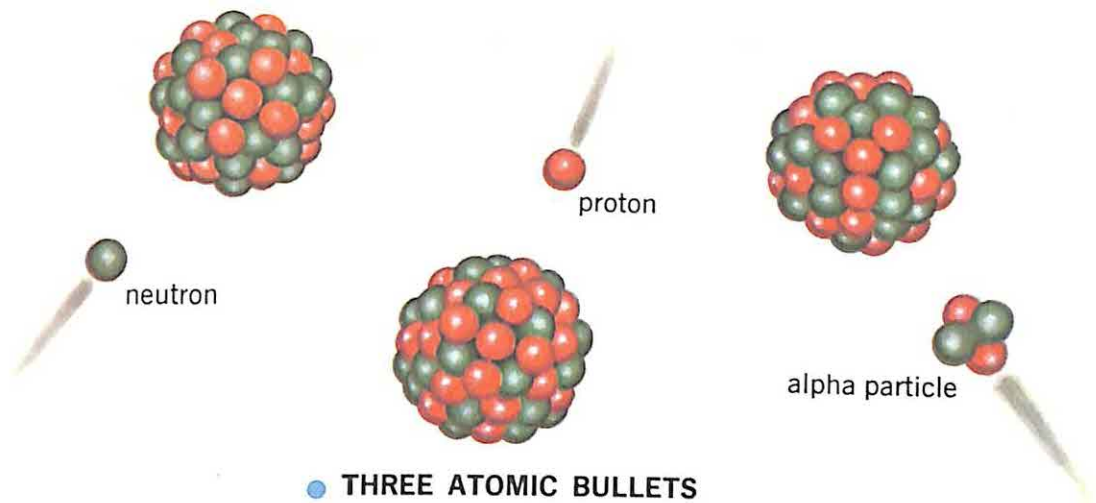
breaks into two or more smaller nuclei, thus creating different elements. Completely different elements may be formed. Some of the elements that are produced when the nuclei of uranium atoms fission are barium, krypton, cesium, and rubidium.

The previous page shows nuclei formed from fission of a uranium nucleus. From the table on page 291, find the number of protons in a uranium nucleus. Compare this to the number of protons in a barium nucleus and in a krypton nucleus. Were any protons lost?

An Important Number

Look at the list of important elements in the table on page 291. Notice again the *number* of protons found in each element. This is called the **atomic number**. Look at the illustration which shows the atoms with atomic numbers 1 to 6. ■ Do you see that each element has a different atomic number? It is the number of protons (atomic number) which determines the characteristics of the atom.

Notice that the atomic number of carbon is 6; that is, carbon has 6 protons. If one proton were added to the nucleus of carbon, it would have 7 protons, and the atom would no longer be carbon. What would it be? Look in the table and find the atom with 7 protons (an atomic number of 7). That atom is nitrogen. By adding one proton to the nucleus of a carbon atom, it can be changed to a nitrogen nucleus.



The neutron then is not the only kind of “bullet” that can cause changes in the nucleus of an atom. Read on to find out about other kinds of atomic bullets—kinds that must be shot from a kind of “atomic gun.”

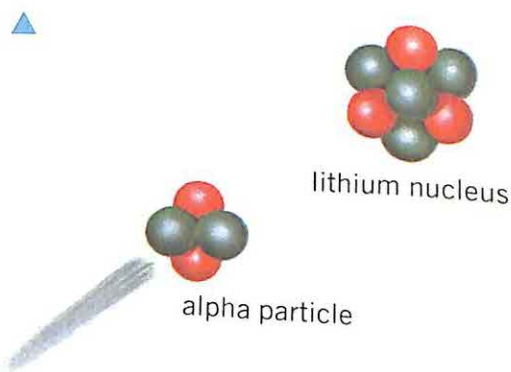
Bullets from an “Atomic Gun”

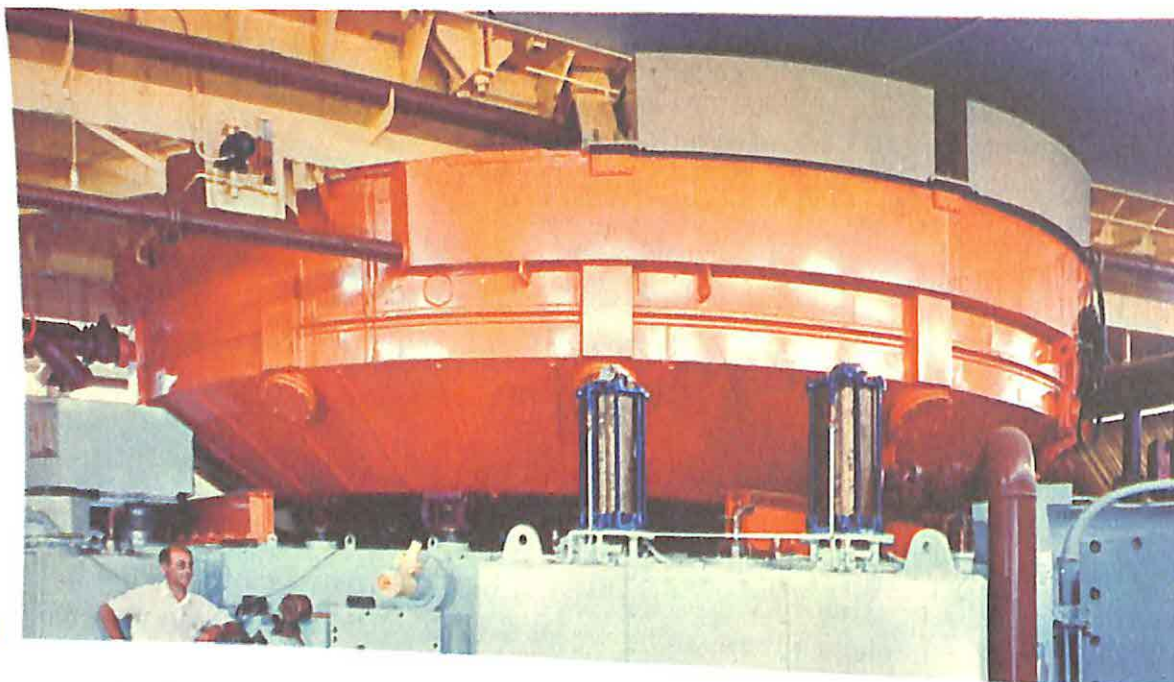
The neutron, a tiny particle with no electric charge, can be shot into the nuclei of certain kinds of atoms to cause fission. Suppose a “charged bullet,” an electrically charged particle, were to be shot into the nucleus of an atom. What would happen? The proton, which has a positive (+) charge, can be used. You can get protons by using the nucleus of a hydrogen atom which has one proton.

The nucleus of a helium atom, which has two protons and two neutrons, can be used also as an atomic bullet. It has a positive charge and is known as an alpha particle. (Remember that alpha particles were given off by the radium samples that were studied by Madame Curie.)

A helium nucleus (with an atomic number of 2) may be used as the bullet to hit a nucleus of lithium (with an atomic number of 3). A nucleus of boron (with an atomic number of 5) results.

The problem of hitting a nucleus with a single proton or with another charged nucleus, such as an alpha particle, is not easy. What is the electric charge of the nucleus of an atom? It is plus (+), because the neutrons have no charge; the protons do. Particles having like charges repel each other, so the nucleus of an atom would normally repel a proton. Unless a proton moves fast enough to over-





come the force of repulsion, it will be pushed away (repelled) by a nucleus. The problem then is to increase the proton's speed.

One way to make protons move fast enough to hit a nucleus is to use an "atomic gun." This is not the kind of gun found in science fiction movies. An atomic gun is a huge structure. One type of atomic gun is the **cyclotron** (sī'klō·tron). ■

The "bullets" used in a cyclotron are either the nuclei of hydrogen atoms (protons) or the nuclei of helium atoms (alpha particles).

In the cyclotron, then, the atomic bullets, the positively charged particles (protons or alpha particles), can be shot at very high speed. The nuclei of different atoms are the targets. When a proton hits a nucleus, the nucleus may change. In this way new atoms may be formed.

In scientific terms, the cyclotron is a nuclear **accelerator**. It *accelerates*, or speeds up, the motion of the nuclear particles. It has helped scientists to learn more about the nature of the atom. The cyclotron was invented by an American, Dr. E. O. Lawrence.

Inside the cyclotron protons are rushed around and around in a circular path, from the center to the outside. ● This speeding up is brought about by adding strong charges of electricity to the two plates called "dees" (each one is shaped like the letter "D"). Huge electromagnets keep the tiny particles in their circular path. They start at the center and travel around and around, faster and faster. Then, finally, these atomic bullets speed out along a straight path to hit the nuclei of other atoms. They often hit their targets and cause the target nuclei to change.

The cyclotron accelerates “bullets” having a positive charge. ● Other types of accelerators may use “bullets” having a negative charge; they may use electrons.

A cyclotron, then, can be used to change the nuclei of atoms. But the nuclei of some kinds of atoms change by themselves.

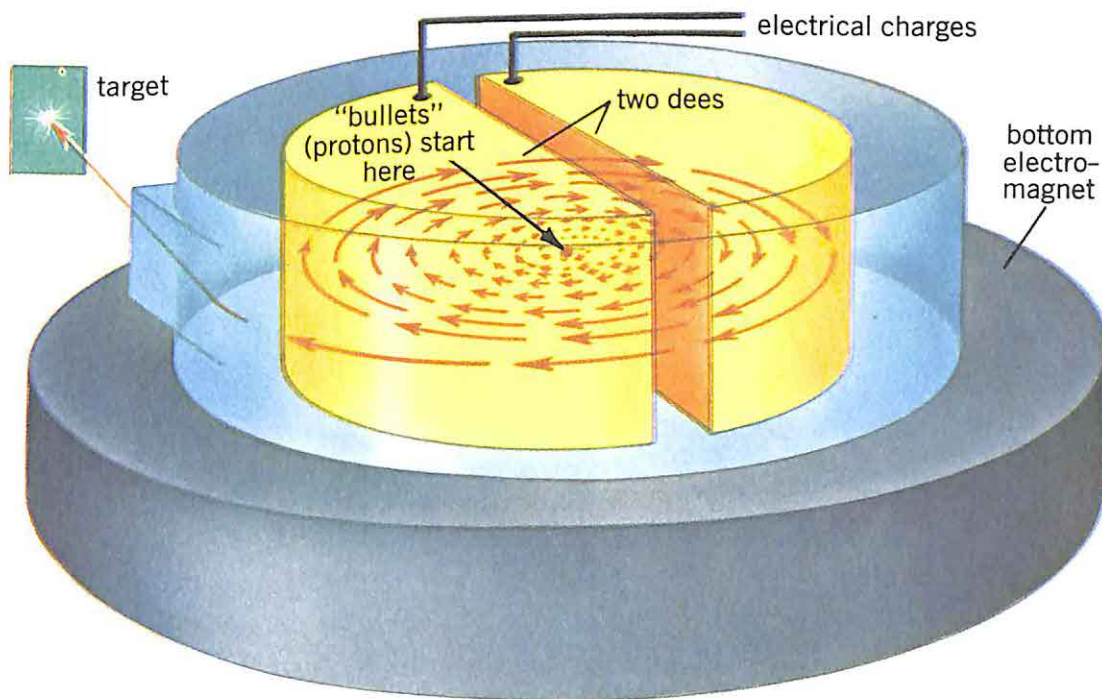
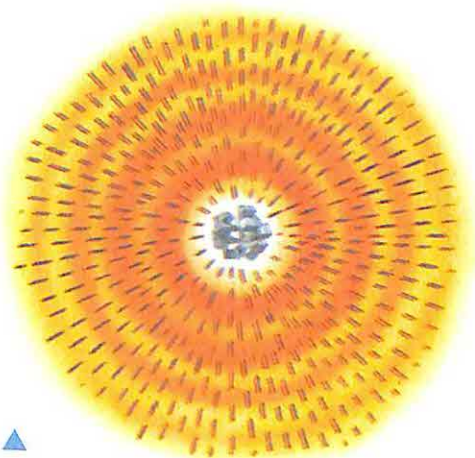
Unstable Atoms

Some kinds of atoms, such as the radium and uranium atoms, have a nucleus that does not hold together very well; it is said to be unstable. An unstable nucleus breaks up by itself, giving off tiny particles and energy. No atomic bullets are needed.

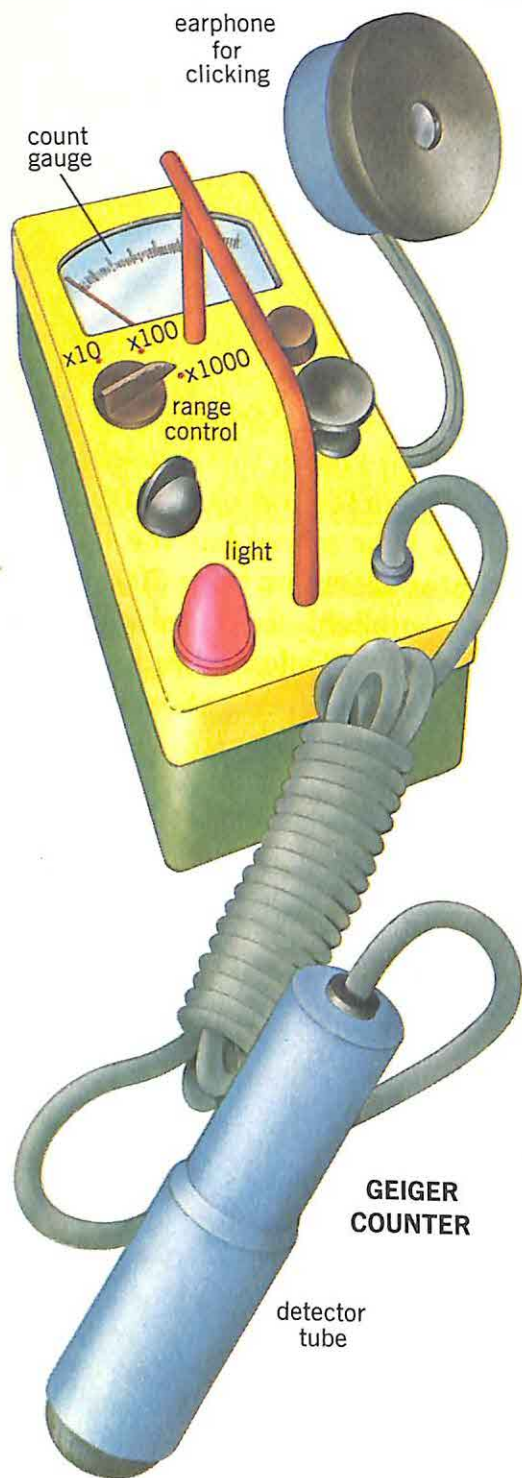
Recall that a substance, such as uranium, which has an unstable nucleus, is radioactive. Because some of its nuclei are always breaking up, a lump

of uranium keeps giving off particles and radiant energy. ▲ Heat energy is one form of energy produced.

How is it known that particles and “rays” of energy are being given off? Perhaps your school has the kind of apparatus shown on page 300. If not, one can probably be borrowed from the local Civil Defense headquarters, for use in the investigation outlined on the next page.



AN INVESTIGATION into the Detection of Radioactivity



Needed: a Geiger counter

The apparatus shown is called a Geiger counter. ■

Notice that it consists primarily of a tube. Each time a charged particle enters the tube, it causes a change in the gas inside. An electric current jumps across the tube, causing either a *flash* of light (in a bulb) or a *sound* (a click). The Geiger counter registers, or counts, particles in the surrounding area.

How many clicks or flashes do you observe per minute? The *counts* let you know how much radiation is present. The counter shows that nuclear particles and radiations are all around us, but the normal amount of radiation in the air is not dangerous. Your Civil Defense director can give you more information about radiation and its effects.

If a radioactive ore, or substance, were to be placed near the Geiger counter, would the counts increase? **An adult should always be present when you test a radioactive substance with the counter.** How useful is the Geiger counter to scientists?

Additional Investigation: Is there a watch with a luminous dial in the school laboratory? Test the watch with the Geiger counter. What radioactive substance might it contain? What precautions should be exercised?

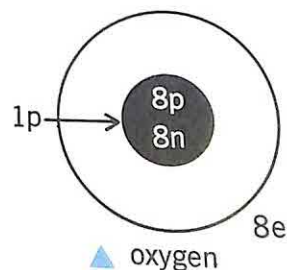
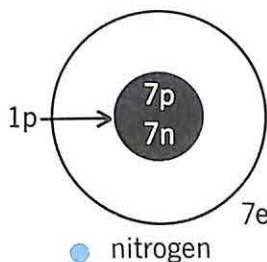
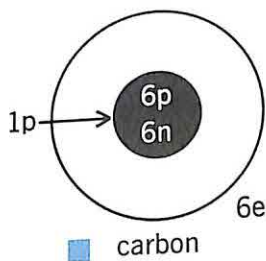
A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. When the nucleus of an atom is split, we say it has undergone
 - a. fission
 - b. charging
2. When an atomic nucleus is split, it gives off particles such as neutrons and
 - a. protons
 - b. heat
3. An atomic bullet which is used by scientists to split an atom is the
 - a. cyclotron
 - b. neutron
4. The atomic number of an atom is its number of
 - a. neutrons
 - b. protons
5. A cyclotron is an
 - a. atomic gun
 - b. atomic bullet

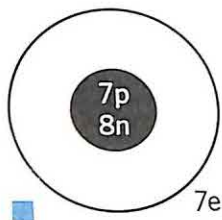
B. Write a paragraph or two on this topic: Splitting an Atom.

To do the following problems, use the table on page 291 and the diagrams of atoms below. ■ ● ▲

1. What atom would be formed in each case if a proton were shot into the nucleus of the atom?
2. What would happen if, instead of gaining a proton, a nitrogen atom were to lose a proton?
3. If the new atoms gained only protons and no electrons, would their charge be positive or negative?



ON YOUR OWN



An oxygen atom has 8 protons and 8 neutrons. What if it lost a proton but kept the same number of neutrons, as shown in the diagram? ■ What atom would this be?

It has the atomic number of nitrogen; therefore it is an atom of nitrogen. But it has an atomic weight of 15. Nitrogen atoms normally have an atomic weight of 14.

Atoms with the *same atomic number* but *different atomic weights* are called **isotopes** (i'sə-tōps). Thus nitrogen with an atomic weight of 15 is an *isotope* of nitrogen.

Note that the oxygen atom has also lost an electron. Would you expect this to happen?

Why not go to the library to find out more about isotopes. For instance, find out

- how they are made
 - how they are used
- Share your knowledge with your class.

3. Nuclear Reactions

When an atomic nucleus breaks up, its particles shoot out in all directions and a great deal of heat is produced. Suppose an engineer had the problem of obtaining heat from an element like uranium. He would need to find a way to break up the nuclei of many atoms of uranium—without an explosion. Such a way has been found. It makes use of an invention known as an **atomic pile**.

In an atomic pile many nuclei split, that is, undergo fission, by a process known as a **chain reaction**. ● To get an idea of how a chain reaction occurs in an atomic pile, we can use our model nucleus made of marbles and a spring marble launcher. ▲ When we shoot a single marble (atomic bullet) at the bunch of marbles (target nu-

cleus), the marbles from the marble nucleus scatter in many directions.

Suppose that as the marbles from the marble nucleus scatter, some of them hit other bunches of marbles, or nuclei. Then these nuclei would also be split. Their particles would scatter and would, in their turn, break still more nuclei.

In an atomic pile, the atomic bullets are neutrons. A speeding neutron hits a uranium nucleus. The uranium nucleus splits up and sends out other neutrons. These neutrons also hit uranium nuclei and cause *them* to send out neutrons. In a very short time, much less than a second, fission after fission of uranium nuclei takes place. On and on this goes, very steadily—neutrons hitting nuclei and freeing other neutrons to hit more nuclei. This process is the chain reaction.

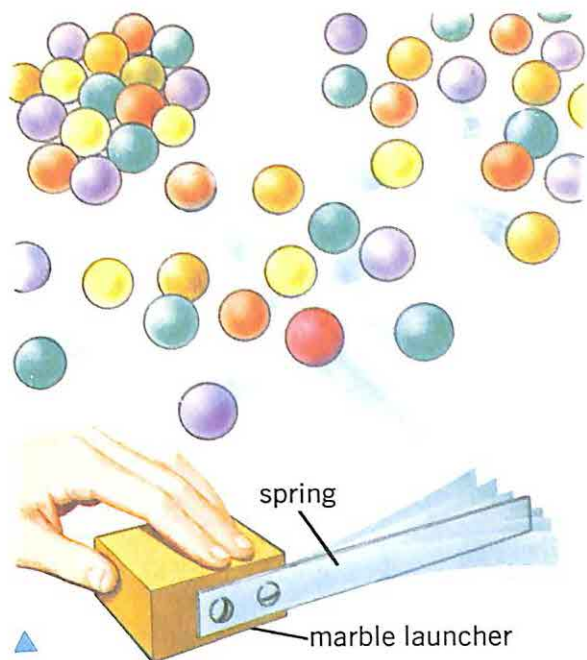
Controlling a Chain Reaction

If the chain reaction were to happen too quickly, there would be an explosion. Rapid fission causes an explosion in a nuclear bomb. A nuclear explosion releases a tremendous amount of heat and nuclear radiation.

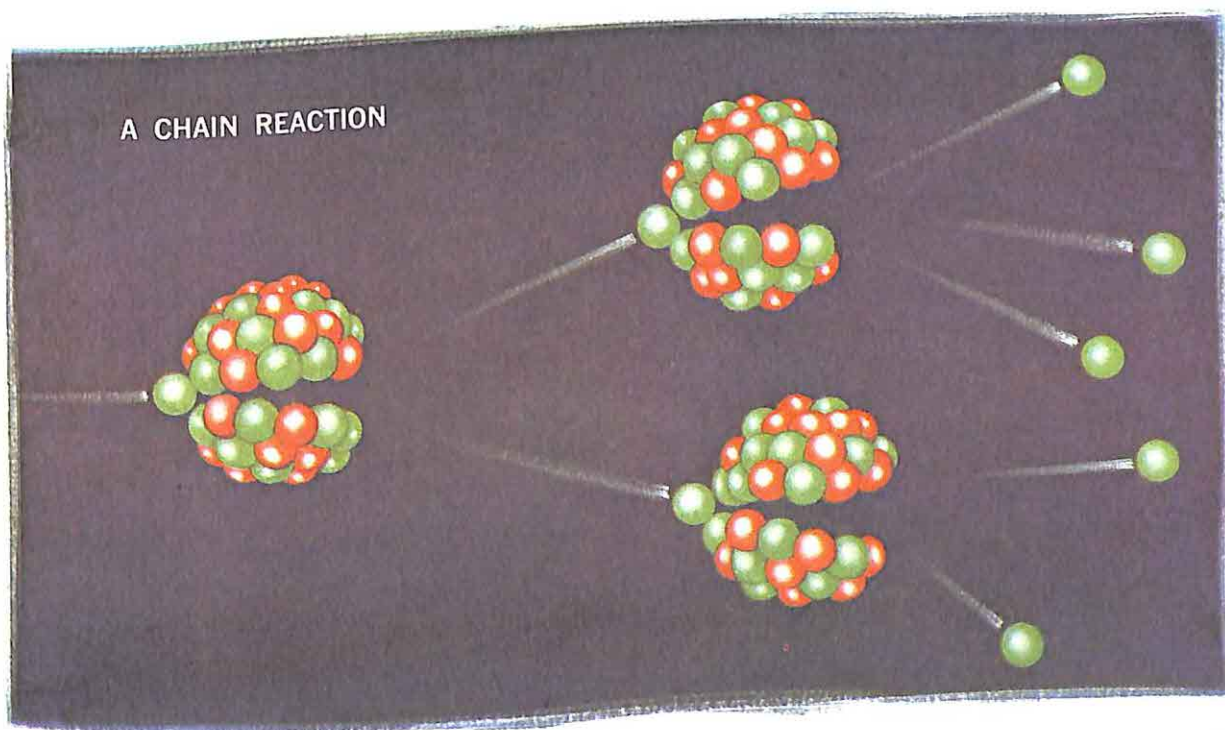
In an atomic pile, however, the chain reaction proceeds as slowly or as fast as scientists may decide. They control the rate of fission and the amount of radiant energy which will be given off.

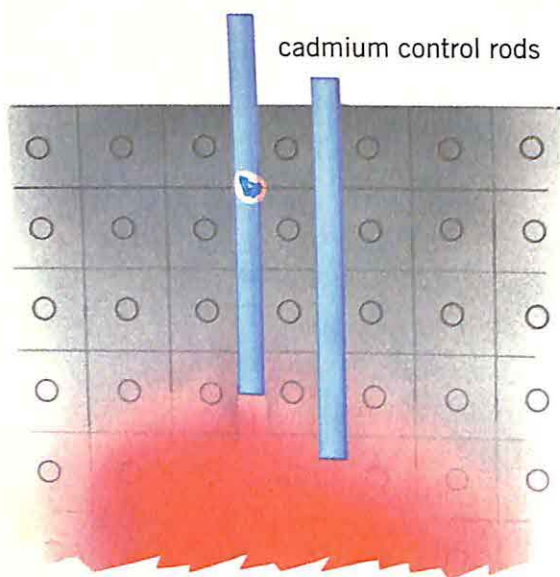
In the early days when atoms were first being split, the devices in which the chain reactions were controlled were known as atomic piles. Today they are usually known as **reactors**. (Notice the similarity between the words *reactor* and *chain reaction*.)

The best way discovered, so far, for slowing down the speed of a chain re-



action is to “soak up,” or absorb, many of the neutrons before they get a chance to cause fission. This can be done with special **control rods** made of the metal cadmium (kad'mē-əm).





The rate of fission is controlled by raising or lowering the cadmium rods into the reactor. ■ The rods absorb many of the free neutrons. This helps the person operating the reactor to control the speed of the reaction. As the rods are lowered even farther, they absorb still more neutrons. The reaction becomes slower and slower

since there are then fewer neutrons to act as bullets. When the cadmium rods are lifted, the reaction speeds up. By putting the cadmium rods in certain positions, scientists can cause the chain reaction to proceed at the speed which they want.

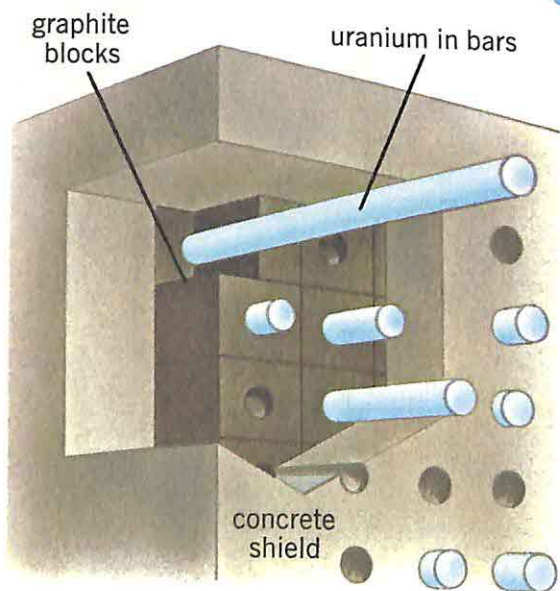
Building a Nuclear Reactor

What is needed to build a nuclear reactor?

First, a substance is needed that has nuclei which break up easily to give off free neutrons (atomic bullets). To get a supply of neutrons, scientists use one kind of fissionable uranium called uranium-235. The nuclei of uranium-235 split apart more easily than ordinary uranium nuclei (known as uranium-238). When the nuclei of uranium-235 are hit by neutrons, they split and a chain reaction is started.

Second, a substance is needed to slow down the neutrons. Graphite is one such substance. Graphite is a form of carbon, the type used in pencil "lead." In some reactors, the uranium is placed in blocks of graphite. ● As the free neutrons travel through the graphite, they are slowed down. Slower-moving neutrons have a better chance than faster-moving neutrons of hitting the nuclei of uranium-235 and causing them to fission.

Third, a material is needed which can act as a "sponge" to soak up excess neutrons, if too many are released. For the "sponge" we may use control rods of cadmium lowered into the center of the reactor.



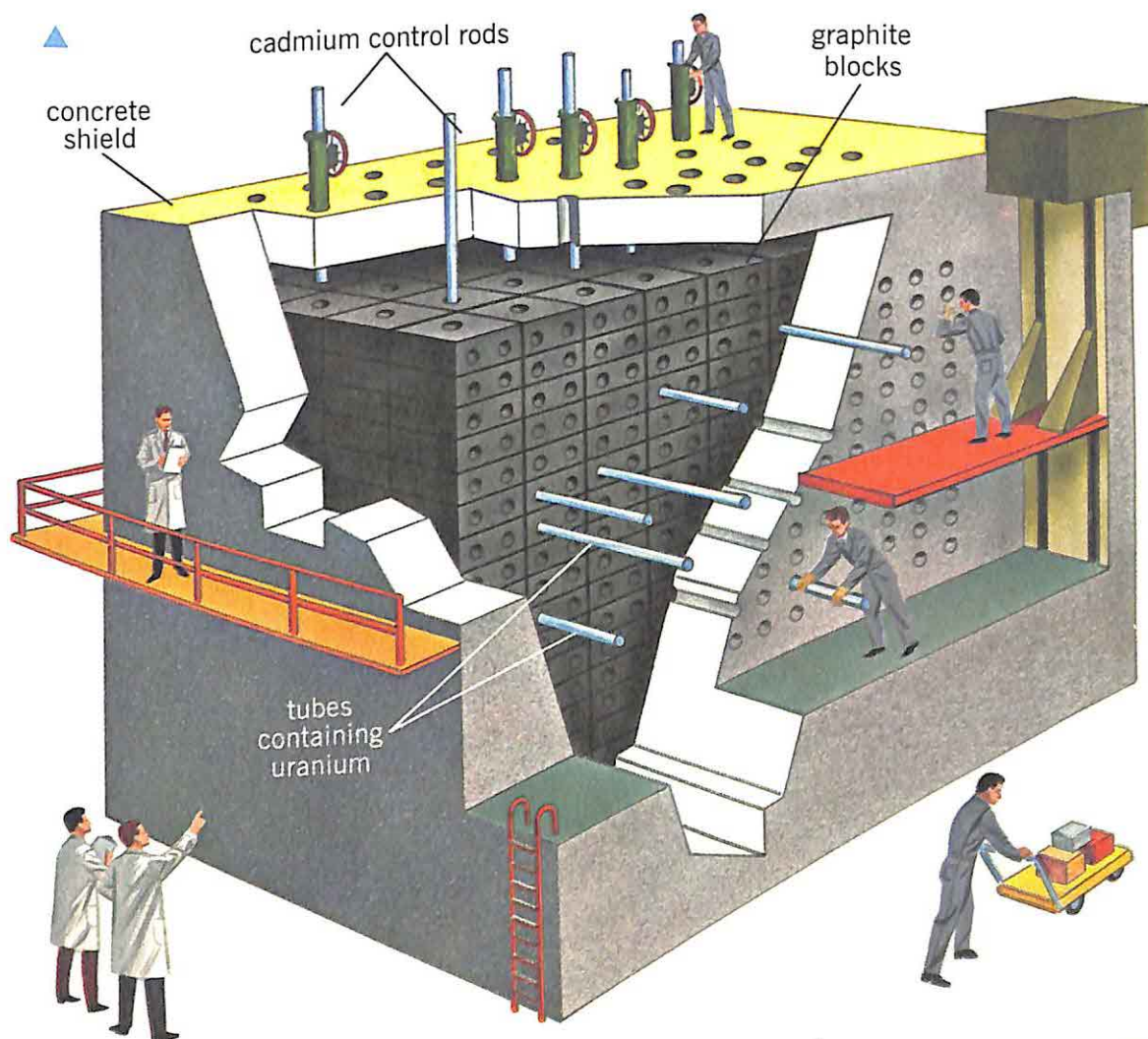
By means of these three basic substances, a chain reaction for nuclear fission can be controlled. In addition, a shield is needed so that neutrons do not escape from the reactor. They can be very dangerous to people nearby.

This is a diagram of an early reactor. ▲ It is the kind of reactor in which the nuclei of uranium undergo fission in a chain reaction.

The speed of the reaction can be controlled by raising or lowering the cadmium rods from the top of the re-

actor. When a chain reaction proceeds very fast, tremendous heat is produced. When it proceeds more slowly, there is less heat at any given time. The object is to control the rate of fission and thus to control the amount of heat that is produced.

Here is a new source of energy, of heat energy in particular. How this energy may be used is described in the next section. First build a model of an early reactor (as shown in the investigation on the next page).



MAKING A MODEL: A Nuclear Reactor

Needed: modeling clay; sugar cubes; toothpicks; shoe box; dominoes and pencils

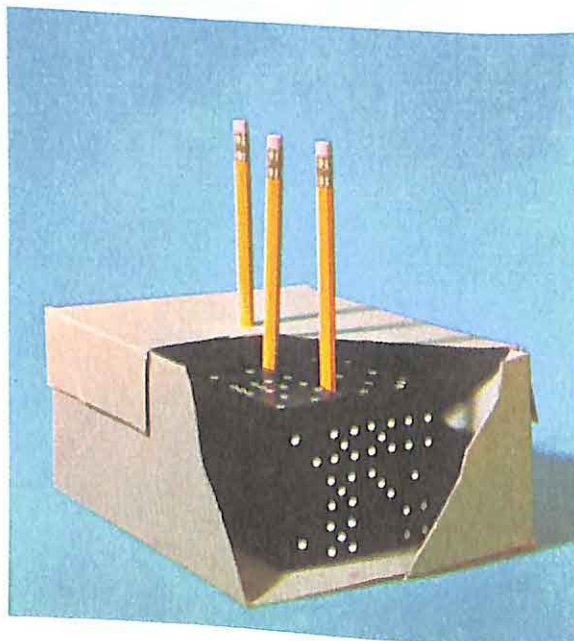
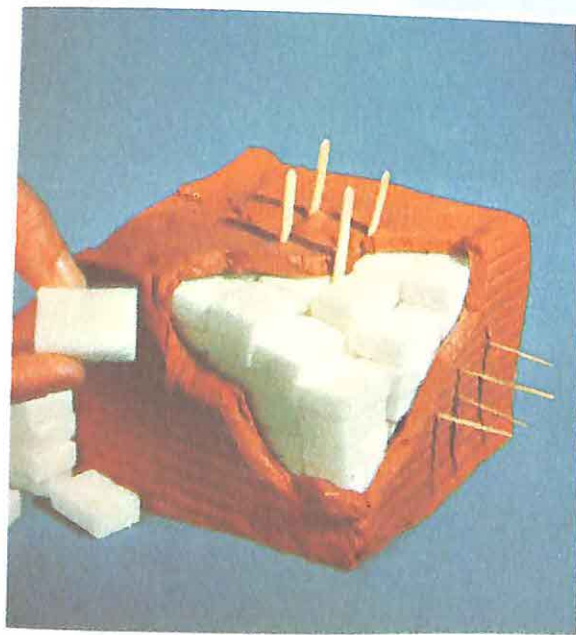
Now that you have studied the structure and function of a nuclear reactor, design a model of one. In designing your model you must keep in mind the factors involved, for example, the dangers of radioactivity. You will need a structure to guard against dangerous accidents; otherwise, neutrons and other radiations will escape from the reactor into the air. These can be very dangerous to living things, especially in large doses.

Escaping neutrons could hit people near the reactor and could cause changes in the nuclei of the elements

and compounds in the human body. Radioactivity may be harmful or even fatal to the human body.

For reasons of safety, then, nuclear reactors are surrounded by a heavy shield to keep neutrons from escaping. The shield may be a thick wall of concrete or of lead. Sometimes it is made of both.

What might you use as a model of the cement shield for your model reactor? A shoe box might be used as a model of these walls. Pencils might be used to show how the control rods are raised and lowered. What would you use as a model for the uranium? for the graphite? Look at the models in the pictures. ■ ● Can you make one that is a better model?



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. In a chain reaction, the particles which act as atomic bullets and cause uranium to undergo fission are
 - a. neutrons
 - b. electrons
2. An invention for getting a controlled chain reaction is the
 - a. reactor
 - b. cyclotron
3. Another name for an atomic pile is
 - a. an atomic gun
 - b. a nuclear reactor
4. To keep a chain reaction going and to increase the chances of neutrons hitting atomic nuclei, neutrons are slowed down by
 - a. graphite
 - b. cadmium rods
5. A substance used to control the chain reaction by absorption of neutrons is
 - a. graphite
 - b. cadmium

B. Write a paragraph or two on this topic: Controlling a Nuclear Chain Reaction.

**USING WHAT
YOU KNOW**

1. Suppose the control rods (cadmium or some other metal) in an atomic pile were missing, what would go wrong?
2. Suppose the heavy shield of cement or lead on the outside of a reactor were missing, what might go wrong?
3. Suppose the graphite (or other substance used to slow down the neutrons) were missing, what might go wrong?

ON YOUR OWN

In some reactors, "heavy water" has replaced graphite as the material for slowing down neutrons. Find out from research in the library what other materials are being used in reactors today—as shields, atomic bullets, sources of neutrons, or replacements for the cadmium rods.

4. Uses of Nuclear Energy

What is the colorful building shown in the picture? ■ Inside the building, huge generators are being turned by steam turbines. They are sending forth great quantities of electricity to the nearby area; but something is missing. Where are the giant smokestacks usually associated with electric power stations? This building does not need smokestacks because it does not use a combustible (burns with a flame) fuel. It has no coal or oil furnaces. Nevertheless, steam is produced easily.

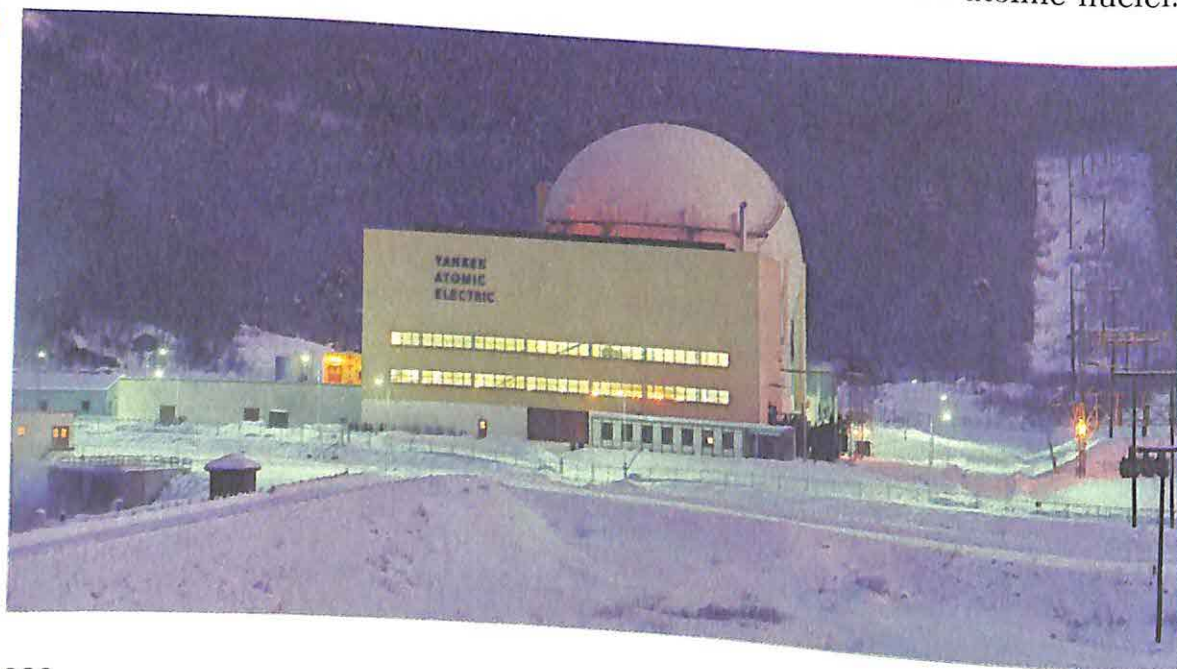
You are looking at a picture of a new kind of power plant, a nuclear power plant. It is the new Yankee Atomic Electric Power Plant in Rowe, Massachusetts. The heat energy used to produce the needed steam does not come from a combustible fuel but from a nuclear reactor.

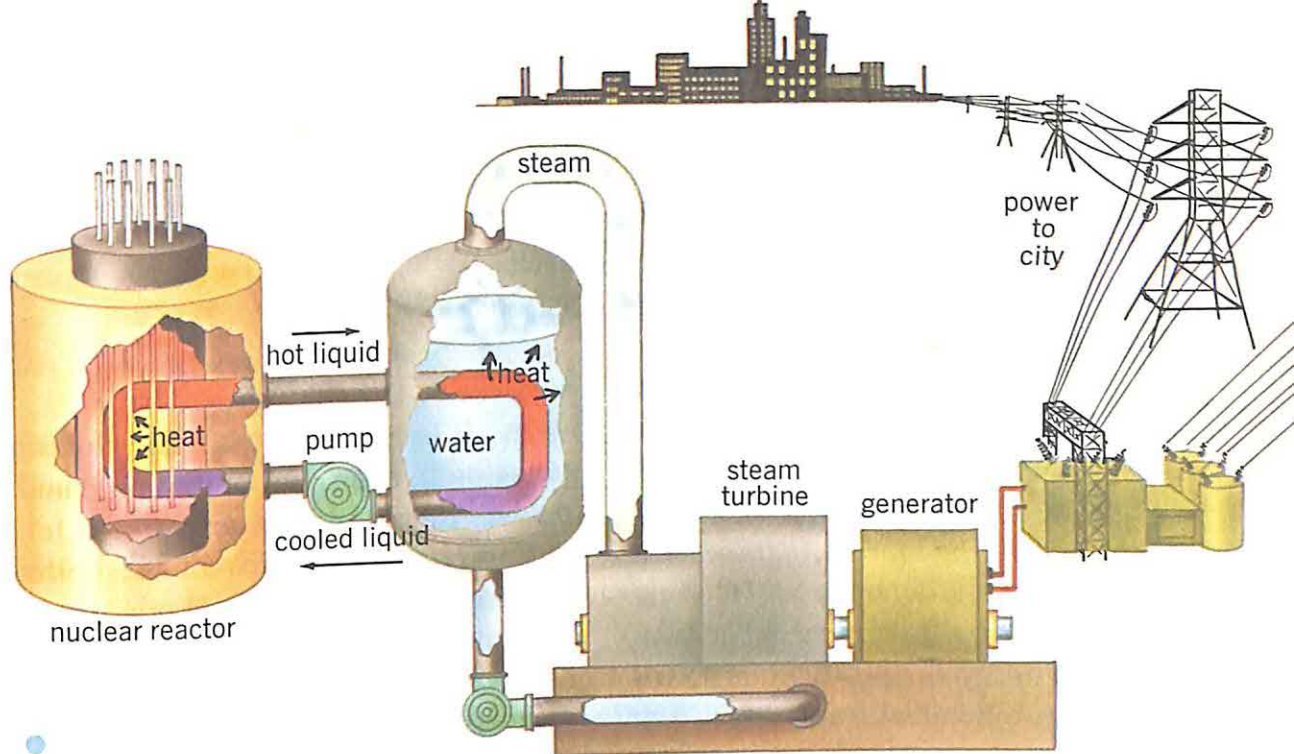
As we have seen, the nuclei of uranium atoms undergo fission in a nuclear reactor. A chain reaction results. Great amounts of heat energy are produced. How is the heat energy changed into electric energy in a power plant?

Nuclear Power Plants

Suppose the heat from nuclear fission, instead of from coal or oil, could be transferred to the water in a boiler. It, too, could change the water into steam, steam that could then turn a turbine. The turbine, we know, would turn a generator to produce electricity. The diagram will remind you of the different steps in this process. ●

First, atomic nuclei are split inside the reactor. Uranium atoms are still most commonly used although atoms of other elements are also being used. Great amounts of heat are produced from the fission of the atomic nuclei.





The rate of fission is controlled, or regulated, by the control rods.

Second, the heat is transferred to a pipe containing a liquid (often a liquid metal) under pressure. The liquid is pumped around inside the pipe, as shown. It carries heat energy from the reactor to the boiler. The heat is then transferred from the hot liquid to the water in the boiler, changing it to steam. As the liquid in the pipe gives up heat to the water, it cools, returns to the reactor, and is again heated.

Third, the steam produced is used to turn turbines.

Fourth, these turbines turn a generator that produces electricity.

Fifth, the electricity can run motors or bring light and heat to homes. Small nuclear power plants can also

be used to generate electricity in submarines and for many other purposes.

Thus, in the nuclear power plant, nuclear energy has been changed into electric energy. Nuclear power plants of this type are already in use today to provide electricity to homes and factories in several areas.

The nuclear power plants are very heavily shielded to prevent dangerous radiation from escaping. The people working inside the plants are also protected by careful shielding of equipment, and by other safety measures.

The operation of these plants is proving that the energy locked up inside the atomic nucleus can be used for peaceful purposes with safety.

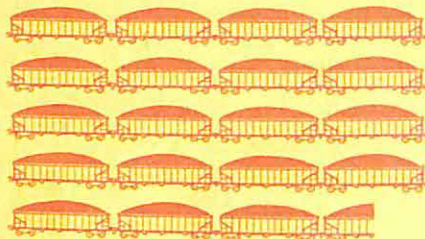
Energy can be changed from one form to another. In an ordinary power plant, what changes in energy take



energy
from
the
fission of
one pound
of uranium

equals

the energy
from burning
2,300,000 pounds
of coal
(enough to fill
19½ freight cars)



place? First, heat energy may be obtained from burning coal. The heat energy is used to change water to steam. The energy of the steam, which comes from the energy of moving molecules, turns a turbine. The mechanical energy of the turbine drives a generator which transforms mechanical energy into electric energy.

In a nuclear power plant, many of the same changes in energy take place. Moreover, the electric energy produced by using nuclear fission is the same kind as the electric energy produced by the burning of coal. But there is a very important difference between a nuclear power plant and an ordinary power plant. That difference can be seen in the diagram. ■ How does the energy obtained from a pound of uranium compare with the energy obtained from over 2 million pounds of coal?

Reactors in Power Plants

At Shippingport (Pennsylvania), Detroit (Michigan), Indian Point (New York), and Rowe (Massachusetts), reactors are now in use in power plants that produce electricity for factories and homes in nearby

cities. It is expected that many other cities will soon be obtaining their power from nuclear energy.

The reactors are, of course, better developed than the atomic pile shown on page 305. For instance, substances other than graphite may be used to slow down the neutrons. The uranium, instead of being placed in blocks of graphite, may be mixed with a liquid which, like graphite, slows the movement of the neutrons. Yet all these reactors still need and use substances which serve the four main purposes with which you are familiar.

1. A substance is needed which gives off neutrons as its nuclei split.
2. A substance is needed which can slow down the neutrons just enough so that they can cause other nuclei to split and give off neutrons.
3. A substance is needed to control the speed of this chain reaction.
4. A substance is needed to act as a shield against escaping neutrons.

Nuclear Energy for Defense

The great heat that is produced in nuclear reactors is now being used to provide energy to drive submarines and aircraft carriers.

Have you read accounts of the voyages of nuclear submarines, such as the *George Washington* or the *Patrick Henry*?² Have you perhaps seen pictures of the new nuclear aircraft carriers with room for many, many planes? These nuclear-powered ships are a part of our country's defense.

In a nuclear submarine, a reactor provides the energy needed to turn the turbines, which turn the generators; these then turn the propeller, which drives the submarine through the water. The engine of a nuclear submarine is shown on the next page.

Because a reactor uses so little uranium, the submarine can travel for thousands of miles on one supply.

A submarine which obtains its energy from ordinary fuel, rather than from a nuclear reactor, would have to stop several times to obtain more fuel to travel the same distance. Nuclear submarines have gone around the world, as well as under the ice cap at the North Pole. They can travel great distances under the surface of the ocean.

Some of these nuclear submarines carry rockets that are fitted with nuclear bombs, which can be fired while the submarine is still below the surface. Such rocket missiles are remote-controlled to hit a target many miles away. Nuclear submarines carrying rockets now can travel great distances in defense against attack.



In a nuclear reactor, the chain reaction is controlled. Nuclei after nuclei split, but at a controlled rate—that is, only a certain number of nuclei split at a time. In this way fission can go on indefinitely. A nuclear explosion, however, is an expanding chain reaction that happens very fast. When a nuclear bomb hits its target, the entire chain reaction is completed in a small part of a second. An unbelievable amount of energy is given off at one instant. That is why a nuclear bomb causes tremendous damage.

The very power of nuclear energy may keep the world free of war. A nuclear war, with the nuclear power available today, could probably destroy every living thing on the earth. Because total destruction is so unthinkable, it is hoped that war itself will become unthinkable.

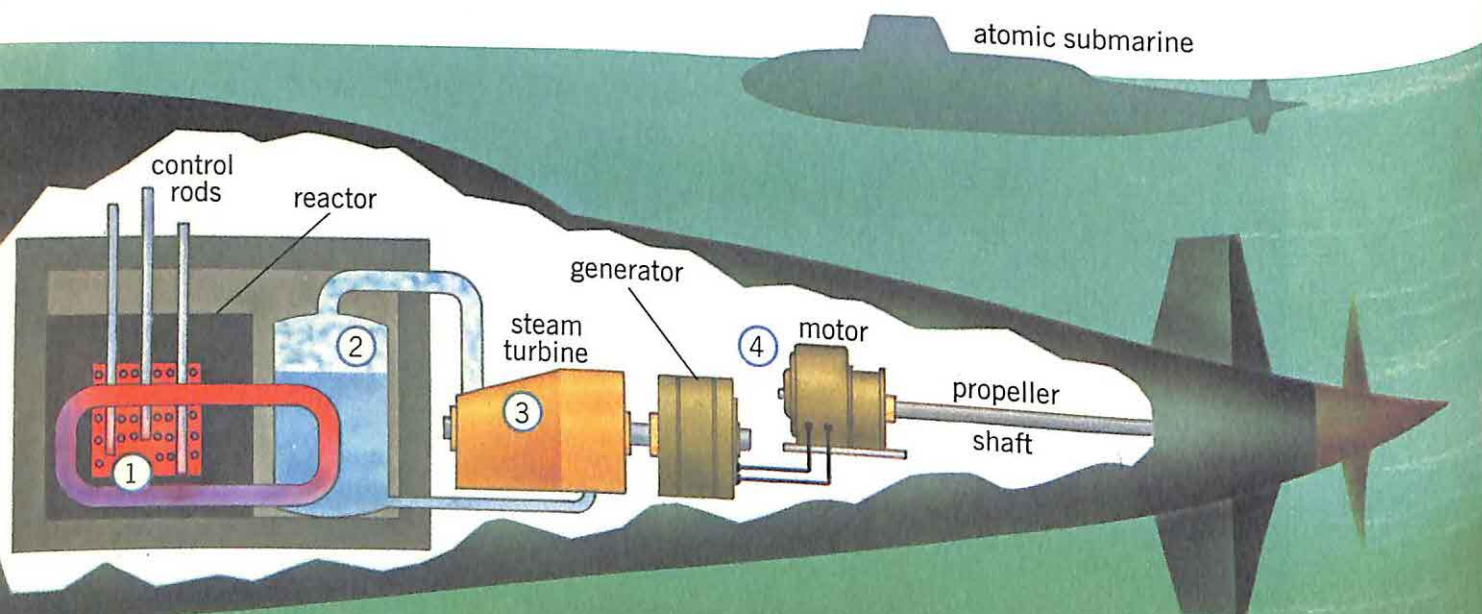
Nuclear Energy Against Disease

The work of Marie and Pierre Curie has had great benefits. It has led, for example, to the control of radium and other radioactive substances, which have since been used in the treatment of cancer.

A cancer is a growth of diseased cells in the body. A cancer gets in the way of the normal functioning of the healthy organs in the body.

Because the radium nucleus is radioactive (unstable), it breaks down. As it does so, it gives off radiations that can destroy some cancers. Nowadays, radium and other radioactive substances are used in such a way that their radioactivity can be directed at any spot in the body.

For instance, the patient shown in the picture is being treated in a hospital. ■ The big machine uses a piece of



radioactive substance; but in this case, the substance is not radium, but radioactive cobalt. The nuclei of the radioactive substance send out atomic radiations. In other words, the machine is a kind of radioactive gun. When the radiation from this radioactive gun is aimed at a cancer, the radiation can be made strong enough to destroy cancer cells without causing great harm to healthy cells nearby.

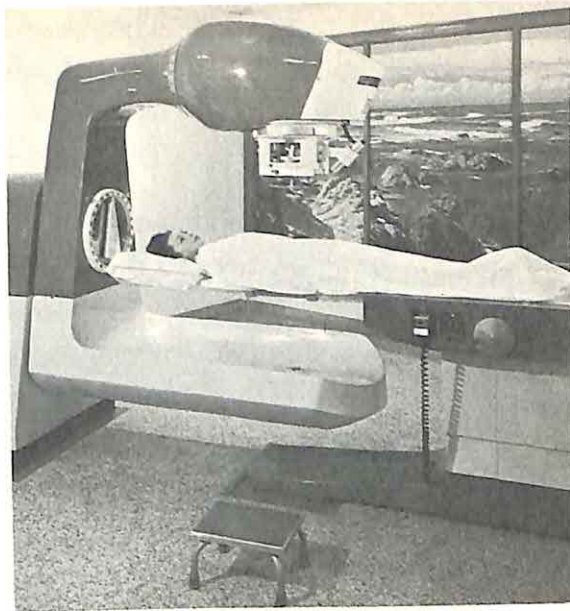
Radioactive substances are now being used not only to treat disease but also for many kinds of medical tests. The advantage of using radioactive atoms in testing is that the path of these atoms through the body can easily be traced with the use of a Geiger counter.

Here is how one such test works. Your thyroid gland absorbs iodine from your blood. If this gland becomes diseased it may absorb iodine too slowly or too quickly. To test whether this is so, a person is given a tiny, harmless amount of radioactive iodine. How long it takes for the thyroid gland to absorb the radioactive atoms is determined with a Geiger counter.

BEFORE YOU GO ON

This time, to fix the concept of nuclear reactions and the uses of nuclear energy in your mind, begin a book of your own entitled: *The Nuclear Age*. You might use an ordinary loose-leaf notebook. Divide the notebook into at least five parts. You may want to have more parts in it later on. The five parts may be:

- a. The Uses of Nuclear Energy in Health
- b. The Uses of Nuclear Energy in Industry



More and more often, nuclear reactions are being used. They are being used to give us electric energy for home and industry and to operate ships and submarines for military purposes. As you have seen, they are also being used to treat disease and to make various kinds of medical tests.

Nuclear energy has become one of the most powerful servants to work for us. In nuclear energy there is a great promise for an even more remarkable future—if it is used wisely.

- c. The Uses of the Atom as a Source of Energy (for Heat, Light, Electricity)
- d. The Uses of Nuclear Energy in Space Exploration
- e. The Uses of Nuclear Energy in Military Operations

Under each section, you can keep records of any new advances in the uses of nuclear energy. Where will you get your material? Here are some possible sources:

1. Newspapers (you may wish to paste in clippings or to write your own reports).
2. Magazines;
3. Reports on television or radio.

You may find many other sources of material as well. New uses of the atom are being developed so fast, it is very helpful to keep an up-to-date record of them.

Perhaps you and your classmates may decide to work on one book together.

5. The Main Concept: Particles of Matter

Man's early understanding, or concept, of the composition of matter has changed.

Before the early Greeks (more than 2,500 years ago), people thought that all the things about them were made up of fire, water, air, and earth. Some of the early Greeks thought the same.

The Greeks went further, however. Leucippus and his pupil Democritus developed the idea that all matter was made up of atoms, atoms that were invisible and indivisible. How else, Democritus asked, could we explain what would happen if we kept dividing a piece of copper until we reached the very smallest particle of copper.

That tiny particle he visualized (imagined) as an atom.

However, neither Leucippus nor Democritus investigated atoms. Their idea of the atom was a result of their thinking only, and was not based on any investigations in the laboratory.

Since the time of Democritus, many scientists have searched for a more complete understanding of the composition and behavior of matter. There were many scientists who contributed to this understanding. Among them were Robert Boyle, a Scottish scientist; Joseph Priestley, an English minister; Antoine Lavoisier, a French scientist. There was John Dalton, an English school master, who did his work early in the nineteenth century. He investigated many different com-

pounds, including water. He, too, accepted the concept that the atom was tiny and *invisible* and, furthermore, that it was *indivisible*. His work was based on investigation that was limited by a lack of equipment.

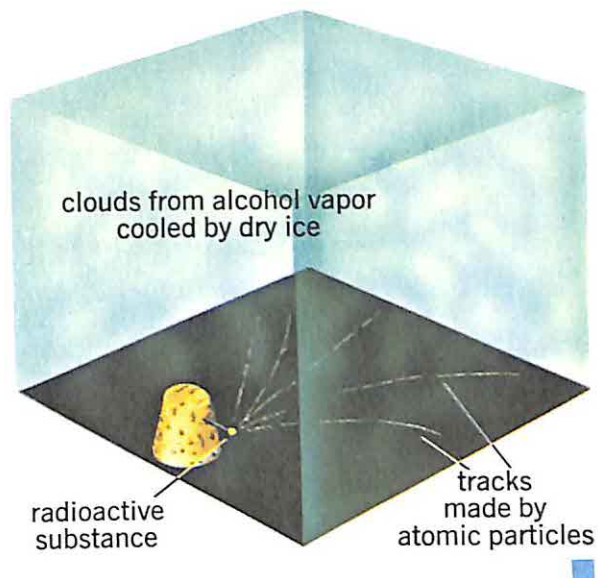
Then came Madame Marie Curie, who found, by investigation, that an atom of radium is not indivisible, that atoms of radium decay (break down), and give off particles smaller than atoms. Other scientists began to find that the same was true of other atoms; in short, they *confirmed the concept* that the atom was made up of smaller particles.

Technologists helped develop ways to investigate atoms and their **sub-atomic** (smaller than atoms) **particles**.

“Seeing” Atomic Particles

Have you ever seen a jet airplane flying very high in the sky? It leaves a track of frozen moisture (vapor trails) in the cold atmosphere.

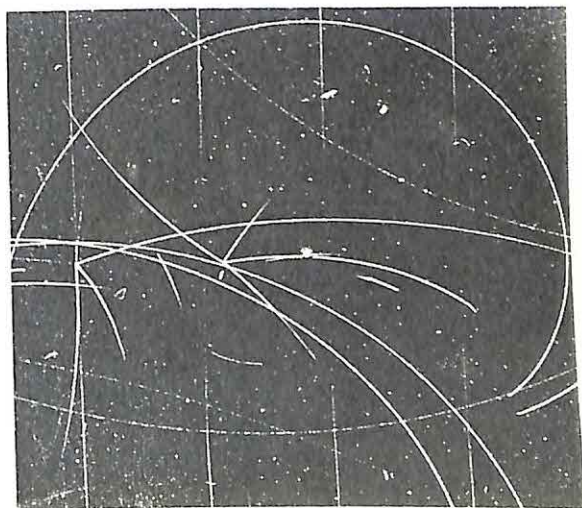
Charged atomic particles leave a kind of cloud in a Wilson cloud chamber, as shown. ■ Particles from an atom pass through invisible vapor, and the vapor condenses to give a cloud-like trail along the path of each particle. In this way, the particles leave a clear record of themselves, as shown in the picture. ● The tracks differ for each kind of particle, whether proton, alpha particle, or electron. Scientists have studied the way particles move in this cloud chamber (invented by Charles Wilson in 1911) and have discovered that they can

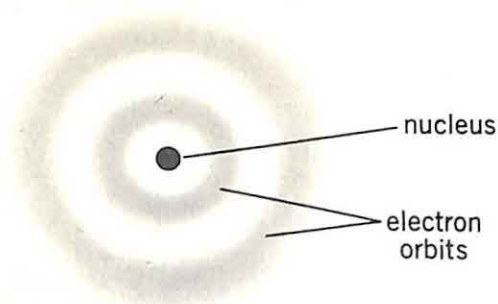


name the different particles by the way they move and by the curvature of their paths.

There are other ways of detecting atomic particles. They have been studied as they were hurled at high speeds from a cyclotron and as they were produced in atomic piles and reactors.

The old concept of the atom as invisible and indivisible had to be changed. It has been replaced by the ●





new concept of an atom that is made up of subatomic particles—electrons, protons, and neutrons.

Niels Bohr, a Danish scientist, defined the new concept. This concept describes the atom as having most of its weight concentrated in the nucleus—in its protons and neutrons. Moving around the nucleus are electrons. The electrons are sometimes described as being in orbit around the nucleus, as planets are in orbit around the sun. Some scientists picture the electron orbits as clouds about the nucleus. ■ The darkest areas show where the electrons are most often located.

The atom is a source of tremendous energy. Because the nucleus of the atom is divisible, *fission* can take place. The energy released by nuclear fission of uranium, for example, can be harnessed to serve man.

Energy released by nuclear fission is far greater than energy released by chemical changes in matter, such as the burning of fuels. Man's new concept of the atom as divisible makes it possible for him to control this vast energy from fission for his own uses.

Nuclear energy from another source has been serving man as long as he has been on this earth! This is the energy from nuclear **fusion** (fyōō'zhən) in the sun. Nuclear energy from the sun lights the earth and supplies green plants with the energy they need to make food. That energy supports all forms of life.

You will read more about nuclear fusion in Unit Nine; but first let us find out more about life, and living things, here on earth.

Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts in this unit by doing these problems.

1. A theory is a reasonable explanation of the facts. Which of these theories on the structure of the atom would you accept?

a. An atom is indivisible.

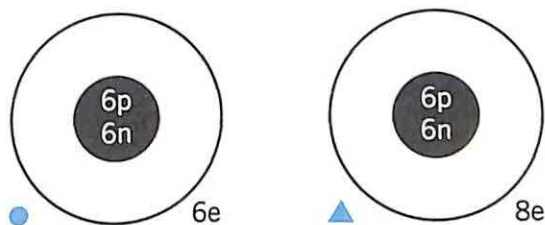
b. An atom is divisible.

2. Below are two statements on the structure of matter. Which would you accept as being more accurate?

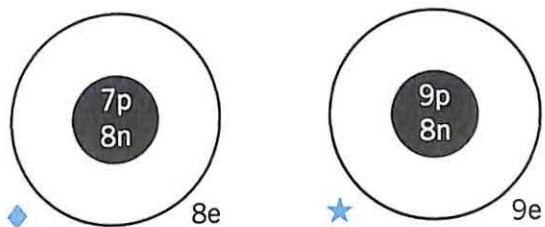
- The smallest particles of matter are molecules and atoms.
- The smallest particles of matter are protons, neutrons, and electrons.

3. What are some of the problems in building a nuclear reactor, and how have they been solved? In your notebook, report how some of these problems have been met.

4. Which of the following would you consider to be a correct model of an atom? ● ▲ Can you explain why? Draw the correct atom model in your notebook. Next to the model, explain why its structure seems correct. Explain, also, why you have not chosen the other atom.



5. Which of the following models of an atom is correct? ◆ ★ As in problem 3 above, draw the correct model in your notebook, and give the reasons for your choice.



6. A sodium atom has an atomic weight of 23. It has an atomic number of 11. In your notebook, draw a model of the sodium atom showing the number of protons, neutrons, and electrons in it. Use the symbols for these particles that are used in the models of the atoms above.

QUICK TEST

1. Copy the following table in your notebook, and fill in the missing information. ■ You should be able to figure out the missing information from the information that is already given. If you need help, read again Section 1 of this unit, which describes the structure of the atom. Compare your figures with those from a reliable source.



Element	Atomic weight	Atomic number	Protons	Electrons	Neutrons
oxygen	16	8			
nitrogen	14	7			
sulfur	32	16			
aluminum	27	13			
copper	64	29			
iron	56	26			
uranium	238	92			

2. In your notebook, draw a model of one of the last three atoms listed in the table, and show the number of protons, neutrons, and electrons in it.

3. Suppose a proton were shot into the nucleus of a sulfur atom, so that its atomic number would be raised by one. What element would be produced? Look for the answer in the table of elements on page 291.

4. Suppose the nucleus of an aluminum atom lost a proton, so that its atomic number would be lowered by one. What element would be produced? To answer this, you will again need the table of elements on page 291.

5. Some of the statements below are correct, but some are not. When you find a statement that is incorrect, decide how it can be changed to make it correct. Write the correct statement in your notebook.

- a. An atom is made up of smaller particles.
- b. An electron is heavier than a proton.
- c. The atomic weight of an atom is equal to the sum of its protons and neutrons.
- d. In an atom the number of electrons is equal to the number of neutrons.
- e. In an atomic pile or reactor, fusion takes place.
- f. In the sun, fission is the source of energy.

FOR YOUR READING

1. *Giant of the Atom: Ernest Rutherford*, by Robin McKown, published by Messner, New York, 1962.

Lord Rutherford made many important discoveries about the structure of the atom. For an interesting biography of this famous scientist, read this book.

2. *Atoms, Today and Tomorrow*, by Margaret Hyde, published by McGraw-Hill, New York, 1959.

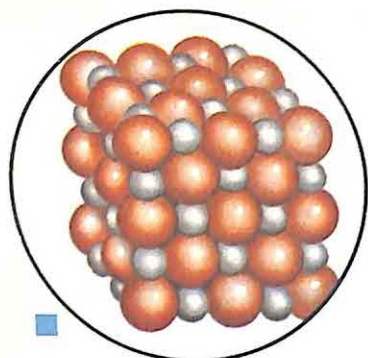
This book tells about the uses of nuclear energy today in medicine, industry, and farming. It also describes plans for future uses of nuclear energy.

3. *Atompower*, by Joseph M. Dukert and John T. Gorsuch, published by Coward-McCann, New York, 1962.

For further information about nuclear reactors, this book is helpful. It shows that although new types of reactors are being designed today, all reactors still have certain basic things in common.

4. *The Curies and Radium*, by Elizabeth Rubin, published by Watts, New York, 1961.

This is the story of the famous husband and wife team and of their important work with radium. It also tells about the work of their scientist daughter and her husband on radioactive substances.



sodium and chlorine



ON YOUR OWN

A crystal of salt consists of the compound sodium chloride. Sodium chloride is made of two different kinds of atoms, as shown in the picture. ■ The larger atoms are chlorine atoms; the smaller atoms are sodium atoms. When combined, these atoms are charged and therefore cling together in an orderly arrangement. Do some research in the library to find out what charged atoms are called.

Suppose each atom of sodium were made as large as the letter "O." What size would you be if you could be made larger in the same proportion? You would be 8,000 miles high. ● You would be about as tall as the diameter of the earth (7,926 miles). A crystal of salt enlarged the same way would be about as tall as a skyscraper (1,200 feet). ■

Does this give you an idea of the size of an atom? It may help you realize how very small it must be.

Suppose a cell in your cheek were enlarged in the same way that the things above were. Recall that the crystal of salt, enlarged, is 1,200 feet high. If the cell were enlarged, it might be $1/100$ of that size. What size in feet would the cell then be?

Recall, too, that an atom of sodium enlarged the same way would be only this high: O. Measure the height of the O. Compare it to the height of the enlarged cheek cell. Can you now figure out how much larger a cell in your cheek is than an atom?

Can you think of other ways of describing or showing how very tiny atoms are?

A Concept of Mass-Energy: A New View

In the world around you are so many different things. In the sea are fish and huge crabs, snails and jellyfish, sand and coral, and mountains poking their heads above the water to make islands. On land there are rocks and houses; rabbits and horses; mountains, hills, and valleys. In the air are airplanes, birds, and clouds. In outer space are stars and planets; moons and other satellites; meteors and dust. In your room are different objects such as paper, paper clips, rubber bands, erasers, chairs, and, perhaps, a desk.

*"The world is so full of a number of things,
I'm sure we should all be as happy
as kings."*

Our world does have a large number of things, as Robert Louis Stevenson wrote. Are all these things quite different from one another, or are there hidden likenesses, or relationships, among all these objects?

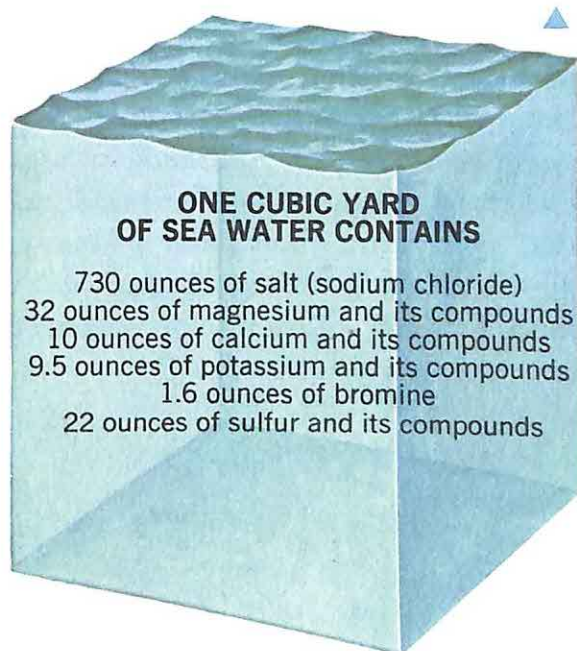
A New View of the World

You know by now that *all* matter—whether in chairs, canaries, air, water, planets—is made up of particles. A substance such as water, for example, is made up of molecules. A molecule of water is the smallest part of water which is still water. If the molecule is broken down, it divides into atoms of hydrogen and oxygen. A substance

such as oxygen, made up of only *one kind of atom*, is an *element*.

Atoms of most elements can combine to form compounds. Atoms of hydrogen and oxygen, for example, combine to form the compound water. Rust, or iron oxide, is a combination of atoms of iron and oxygen. All around you, then, is a world made up of elements and compounds or mixtures of elements and compounds. For instance, seawater is a mixture of the elements and compounds shown in the chart. ▲ Which of these substances are elements?

Everything in the world, living and nonliving, and all the elements and compounds in them are made from some of the 103 different atoms. Impossible? Well, the 500,000 or so words in the English language are



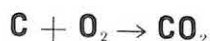
made from only the 26 letters of the alphabet. With 103 kinds of atoms, then, it is possible to make millions upon millions of compounds.

If we probe further, we find more hidden likenesses in matter. When we study atoms with scientific instruments, we find even smaller particles. On page 289 you saw that the atoms of oxygen, iron, nitrogen, and carbon are all made of the same smaller particles—electrons, protons, neutrons.

All the matter about us, then, whether in the form of rabbits, diamonds, or people is made up mainly of three kinds of particles—*electrons, protons, neutrons*. We can sum up the hidden likenesses in matter in the great concept: *All matter is made up of particles.*

Changing Matter into Energy

What more do we know about matter? We once thought that matter could be changed from one form to another but could not be created or destroyed. It is true that *in a chemical change, matter is neither created nor destroyed*. This concept holds for any chemical reaction like the reactions that you know about. For instance, when carbon and oxygen combine to form carbon dioxide, the chemist writes:



1 atom + 2 atoms $\rightarrow$ 3 atoms

3 atoms $\rightarrow$ 3 atoms

The number of atoms of carbon (C) and oxygen (O₂) that go into the re-

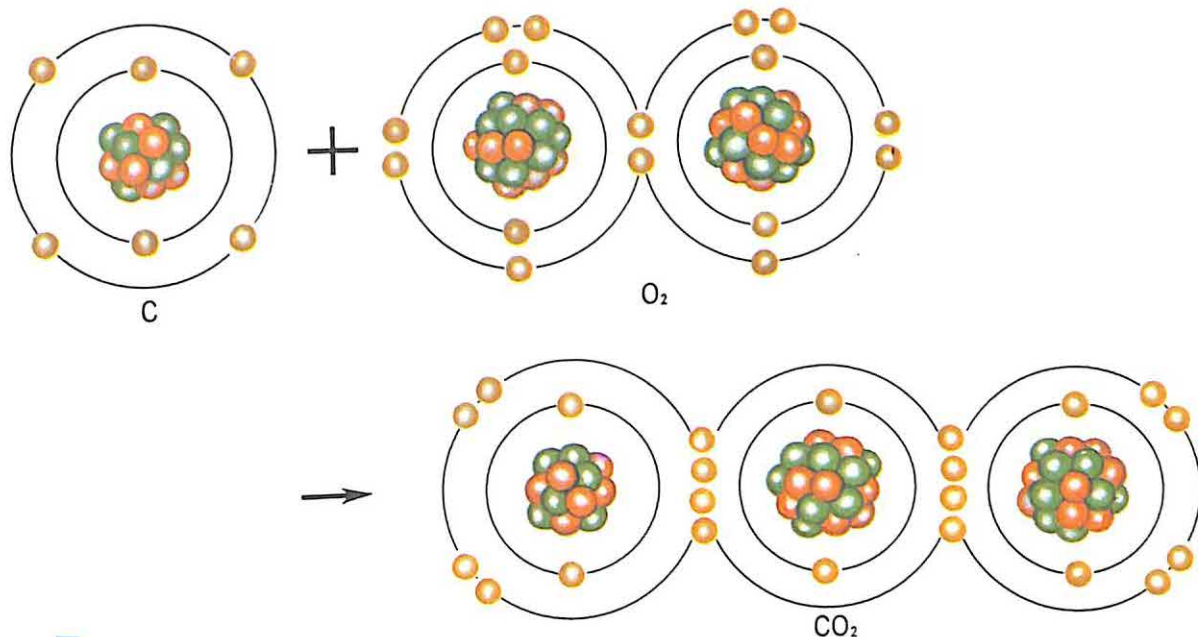
action is always the same as the number of atoms in the molecule of carbon dioxide that is produced. ■

Whenever substances take part in a *chemical reaction*, their atoms are neither created nor destroyed. The same amount of matter that goes into the reaction comes out of the reaction. *In a chemical reaction, the total amount of matter remains the same.*

A *nuclear reaction*, however, is different from a chemical reaction. In a chemical reaction only the electrons around the nucleus take part. But in a nuclear reaction, the nucleus itself is changed. A nucleus may split, and some of its matter be lost. Or two nuclei may join; again, some matter is lost. The nucleus may lose or gain particles. *In either nuclear reaction, some of the matter from a nucleus may be changed into energy.*

If you burn a log, which is a chemical change, the energy stored in the log is changed into heat energy and light energy. The energy is changed in form, *but the total amount of matter remains the same.*

In a nuclear reaction, on the other hand, some matter is changed to energy. Very careful measurements and experiments have been carried out by teams of scientists. Countless calculations have been done, and, in every case, these show that some of the **mass** (amount of matter) has “disappeared.” This matter is not lost; it is changed into energy. In describing a nuclear reaction, therefore, we introduce a new concept: *In a nu-*



clear reaction the total amount of matter and energy remains the same. To show that matter (mass) can be changed into energy, scientists now often use the following term for both: **mass-energy**.

In the fission of a uranium nucleus, for example, some matter is changed to energy. When even a tiny bit of matter is changed to energy, huge amounts of energy are produced. This is what Einstein meant when he wrote:

$$E = mc^2$$

Think of this formula as a sentence in which **E** stands for energy. **m** stands for mass that is lost. **c** stands for the speed of light which is, as you know, 186,000 miles per second. **c²** is this number multiplied by itself—a tremendous number! In a formula, the

two sides balance. Since **c²** on the right side is such a huge number, **E** on the left side must also be huge, even if **m** is very small.

Our concepts today of the way matter and energy behave may be summed up as follows:

In a chemical reaction, matter can be changed in form, but the total amount of matter remains the same. Energy can be changed in form and transferred from one place to another, but the total amount of energy remains the same.

In a nuclear reaction, matter can be changed into energy, but the total amount of mass-energy remains the same.

This last important concept of the way matter and energy behave will guide your future work in science.

CONCEPTUAL SCHEMES

A living thing is the product of its heredity and its environment.

Living things are in constant change.

Unit Eight

CODE OF HEREDITY

(Text pages 324-63)

CONCEPT (Sections 1-4)

The characteristics of a living thing are laid down in a genetic code.

As pupils investigate and analyze their own experiences, they begin to appreciate the great diversity of living things on the earth and, at the same time, see how their characteristics are transmitted from generation to generation. They also become aware of the role of environment in the development of traits, and how mutations (new traits) appear, which breeders and growers can develop according to concepts of heredity that scientific investigation has made clear.

Note to the teacher. It will be seen that this unit is concerned with two conceptual schemes. These schemes are meant to serve the educative scheme; that is, the purposes of education. It is true that the thread of each conceptual scheme should be carried through the development of the pupil as he progresses from grade to grade, and yet the conceptual scheme should be developed in harmony with the pupil's growth. Further, the experiences underlying the development of a conceptual scheme should be within the scope of the general sensory experience available to the pupil.

The pupil can deal with experiences relating to the interaction of heredity and environment; he can, in short, deal with the experiences that lead to uncovering the concepts leading to apprehension of the first of the conceptual schemes listed above and he can deal effectively with the concept that is stated for the first four sections: *The characteristics of a living thing are laid down in a genetic code.* The experiences that serve this concept are basic, in turn, to the experiences underlying a study of the way organisms have changed over the ages, through changes in genes that had survival value. That is, the new genetic trait adapted the organism for better survival in the changing environment. Changes in genes that are inherited are known as mutations. Mutation—change in genes—is important to understanding change in organisms over the ages. While very little direct experience can be obtained with this concept in elementary school grades, it is exceedingly important to make a beginning.

The concept is important to an understanding of the way our world works. In other words, with elementary school children, experiences underlying an understanding of mutation are difficult to come by. Nevertheless, it will be apparent that the concepts for Sections 5 and 6, *Changes in the genetic code produce changes in living things*, serves the conceptual scheme: *Living things are in constant change*.

You may recognize that the term *change*, as used in discussing the development of living things, means that more complex organisms have evolved from simpler organisms during the two-or-more billion years of life forms on earth. It also means that some organisms have not survived because their ability to adapt did not keep pace with a changing environment. Change is related to the interdependence of living things and their environment, whether favorable or unfavorable. Our present-day biological forms have evolved because of their ability to survive in changing environments. The mechanisms of biological evolution are based in complex understandings of the interaction of heredity and environment. Why any organism exists today—why we exist—is rooted in many biological changes and adaptations. If this understanding is firmly grasped, the use of the term *evolution* may have value at this point in the student's development.

Change of course is not limited to living things. In the final unit of this textbook, it becomes increasingly clear that the universe is undergoing constant change—that is, the universe is also evolving. The term *evolution* is therefore applicable to the changes in the universe and may have value in the student's appreciation of the concepts of the way the world works.

A VIEW OF THE UNIT

There are few concepts in science that have more important implications and applications than those flowing from studies in genetics. They bear closely on the riddle of life itself and certainly help explain the infinite variety of living things, their success or failure in adapting to changing environments, and the continuity of generations. Since man has a structure, his brain, that is peculiarly adapted to understanding and interpreting the objects and events in the universe, the implications of the concepts of heredity have particular importance to him. They have importance to individuals as well. How are your pupils going to make the best use of their inherited characteristics? This is the long-range problem that each pupil studying this unit may well be encouraged to give thought to.

Plants may be reproduced from a single parent, as with the potato, in order to preserve in the offspring all the characteristics of the parent plant. Or plants may be grown from seed with some of the characteristics from each parent appearing—or not appearing—in the plant offspring. These effects were known long before the Augustinian monk from Brno in Austria (now Czechoslovakia) performed his carefully controlled experiments on the inheritance of pea plants. This is the background of conceptual understanding pupils are given in the first section.

A Preview of the Concepts

Section 2 presents the historical development of concepts of heredity from Mendel's original experimentation and carefully documented records of over 10,000 pea-plant crosses to the present-day concept of DNA, the large protein molecule that scientists believe is the key to the transmission of traits from parents to offspring. As you work with your pupils, you may well wish to stress that much work needs to be done in many areas, and that present concepts may be revised or new concepts developed. *At present*, there are some good explanations.

The pupil's text for Section 2 does not go beyond the F_1 (first filial) generation. All the daughter plants of Mendel's crosses of tall and short pea plants were tall. This explains the concept of dominance, but does not explain sorting of dominant and recessive genes in the F_2 (second filial) generation. The teaching suggestions for this section carry the sorting of genes (all tall plants) to this next generation, so that you may, if you wish, demonstrate the 3:1 ratio of tall plants to short, or the 1:2:1 ratio of pure tall : hybrid tall : pure short plants. Unfortunately, for many traits, things are not so simple. Scientists, after Mendel, who studied inheritance, found that several traits appear to be linked, and the possible combination of traits is considerably multiplied. However, Mendel's basic concepts still hold, and the pupil builds on a secure foundation by studying inheritance of just a single trait—as Mendel did.

The model of the DNA molecule suggested on page T-162 is easily recognized as oversimplified. If you are interested in why A, T, C, and G have been selected as the letters to mark on the simplified model, A stands for adenine, T for thymine, C for cytosine, and G for guanine. These are complex groups of atoms containing nitrogen, carbon, hydrogen, and oxygen atoms, each group arranged in a different way. Attached to each of these groups are sugar groups to which, in turn, are attached phosphate groups; these differences are suggested by the color code of the model suggested. It sounds complicated—and it is! That is why an oversimplified diagram is suggested which most of your pupils—and certainly your best—can understand, in general. It is desirable to give these pupils an idea of DNA; they will read of it in the newspapers and magazines. If you wish further elucidation for yourself, we suggest you refer to *Life* by George Gaylord Simpson et al., in the latest edition published by Harcourt, Brace & World.

You will not need all this background to present and develop the concepts, but you may be as interested as your pupils—perhaps more so! The later sections of the pupil's text and accompanying teaching suggestions are quite straightforward. However, you may find the following information useful if a perceptive pupil raises questions beyond the usual scope of study at this level.

If each human body cell has 23 pairs of chromosomes, what happens when a male cell and a female cell unite to form the egg cell for the new offspring of two parents? In normal cell division within the body, all the contents of a cell nucleus are duplicated in the resulting cells.

The sperm cell and the egg cell, however, each have only one of the pair of chromosomes (23 chromosomes). On fertilization, the egg has one from each parent. The resulting body cells of the offspring then have the normal 23 pairs for its body cells. This perhaps helps to explain the sorting of traits in the DNA model on page T-162.

The methods of reproducing plants so that the new plants retain all the traits of the parent organism are interesting. The pupil's text mentions grafting, in particular, and the teaching suggestions mention rooting of cuttings. There are, of course, other ways. Many plants are *self-pollinating*. That is, if pollen falls from the stamen to the pistil of the same flower, the offspring have the same traits as the parent plant. Strawberry plants reproduce by *runners*; fleshy roots and other underground parts of such plants as peonies, perennial poppies, rhubarb, dahlias, horseradish, iris, and so on, can be broken up and planted, each bit of the parent organism producing a new plant with all the traits of the parent. Rose plants with identical traits can be propagated by *layering*; that is, by burying the end of a long shoot in the ground until it sends out roots to nourish a new plant from the moisture and minerals dissolved in soil water. Certain types of begonias, sedums, and African violets (*Saintpaulia*) can be rooted by *leaf cuttings*. Some of these ways, if you have the facilities in your school or classroom, may be interesting to develop with the class. For details in care and handling, see pages 156-60 of *A Sourcebook for the Biological Sciences*.

The unit illustrates once again the close teamwork between the scientist, who is seeking concepts, and the technologist, in this instance the plant grower or the animal breeder, who applies the concepts. If, at the end of several weeks of study on the interaction between inherited traits and the environment, your pupils acquire an understanding of the basic concepts and see how they apply to their own growth and development, count yourself fortunate.

SUPPLEMENTARY AIDS

All the films and filmstrips listed are in color, unless otherwise indicated. Most of the visual aids are rated as junior high school in conceptual difficulty; however, they have many useful sections. A preview is suggested as desirable so that the more suitable parts may be used to reinforce concepts. Names and addresses of the distributors and suppliers are on page F-26.

Flowers and Their Purpose (14 min., sound), F.A. Flowers are the part of a plant that lets it produce its own kind. To improve plants, botanists control pollination between especially healthy plants to produce a superior strain. (Intermediate)

The Fruits of Plants (12 min., sound), F.A. Through crosspollination, grafting, and budding, man is constantly producing healthier, better tasting, and better appearing fruits. (Intermediate)

Films

Filmstrips

The Mechanism of Inheritance (14 min.), McGraw-Hill. Like begets like, not by pure chance, but by complex mechanism. Deals with the inheritance of color in plants; crossbreeding of pure plants, blend of color, and effect of dominant and recessive genes. (Junior High)

Heredity (11 min., black-and-white), E.B.F. Explains the transmission of hereditary factors responsible for inherited characteristics of animals. (Junior High)

How a Plant Makes Food (42 frames), McGraw-Hill. Explains how necessary sunlight is for growth of plants; a plant is like a factory that makes and stores its food. (Intermediate)

Man Improves Plants and Animals (37 frames), McGraw-Hill. Shows the many ways we benefit from plants and animals, and the ways in which man has improved them for his purposes. (Junior High)

Heredity (48 frames), McGraw-Hill. Explains why offspring resemble their parents; also why there can be differences; shows experiments verifying Mendel's law, development of hybrids; causes of mutations. (Junior High)

Gregor Mendel (50 frames), E.B.F. Drawings tell of Mendel's experiments with plants to determine how characteristics of parent plants were inherited; shows crosspollination; development of hybrids. Explains Mendel's law. (Junior High)

Science Reading Table

Titles starred (*) are considered as especially suitable for the development of concepts. Other titles have many useful sections. Addresses of the publishers are on page F-24.

**All About Heredity* by Judith Randal, Random House, 1963. An introduction to the science of genetics, from Gregor Mendel's first experiments with garden peas to the latest discoveries about DNA. Part I is entitled "The Framework of Heredity." Part II, "Revolution in Biology." A list of important dates in genetics summarizes the content of the book. Remarkable photographs supplement the narrative. (Advanced)

**Around the World with Darwin* by Millicent E. Selsam, Harper & Row, 1960. An account of Darwin's voyage that made scientific history. He asked himself many questions about the plants and animals he saw and startled the world with his answer—the theory of how living things evolved. (Easy)

The Case of the Missing Link by Eleanor Clymer, Basic Books, 1962. A dramatic story of the hunt for the ancestors of man. The story includes a long string of manlike creatures, but the search for refinement of knowledge and many missing pieces continues. The answer to the question "What Made Man Human?" constitutes a review of the anthropological facts. (Average)

Mangrove Island by Marjory Bartlett Sanger, World Publishing, 1963. Describes the birth and growth of a mangrove island and the wildlife it shelters. The destruction of a mangrove island by a hurricane completes the cycle. The interrelationships of living things and the forces of nature are emphasized. (Advanced)

A *Million Years of Man* by Patrick Lynch, St. Martin's Press, 1959. Traces the history of the earth billions of years ago—from protozoa to prehistoric man. Includes simple explanations of astronomy, geology, zoology, and anthropology. Also illustrates the major concepts of how living things evolved.

(Advanced)

**Plants in His Pack* by Janice J. Beaty, Pantheon Books (a division of Random House), 1964. The story of Edward Palmer, a scientific collector. He devoted his entire life to gathering plants, animals, birds, and Indian artifacts in the American West and Mexico. He collected more than 100,000 different plants for museums and universities. His far-flung adventures make interesting reading.

(Advanced)

**The Wonders of Seeds* by Alfred Stefferud, Harcourt, Brace & World, 1956. Narrates how seeds sprout and grow into plants which flower and bear fruit filled with new seeds. Describes many kinds of seeds and their special characteristics in the cycle of growth.

(Average)

The Story of Life: Plants and Animals Through the Ages by Peter Farb, Harvey House, 1962. Outlines the story of the ways of living developed during the past billion years. Answers questions such as "How has the incredible abundance and variety of life come about?" and "How do we know?" Drawings of remarkable precision supplement the story.

(Average)

► INTRODUCING THE UNIT

How have you changed since you entered first grade? How are you still much the same? Probably most pupils will stress the *changes*. Suggest they look in a mirror. Have your eyes changed? your ears? nose? mouth? But you're right, you have changed. What new characteristics have you acquired? How are you (a boy) different from another boy in the class? How are you (a girl) different from another girl? Are some of these differences inherited from your parents? Are some acquired from the environment—from people around you, or from the kind of food you eat for lunch?

In this unit, the pupils will investigate genes, the basic determiners of heredity—what they are born with, and how environment may affect their development. Tell them so. Also tell them that all living things seem to follow a pattern of growth and development, so we will study plants and animals chiefly. It is important that a sensitive pupil will not withdraw because he feels *he* will be the subject of discussion.

Section 1: A "CHIP OFF THE OLD BLOCK"

Through direct observation under controlled conditions, the pupils begin to see that heredity and environment interact in determining the growth and development of an organism.

(Text pages 326–32)

SUBCONCEPT

Inherited traits interact with environment.

Processes emphasized

Observation

Design of an investigation (with experiment)

Hypothesizing

Theorizing

Building of theoretical models

Analysis of models

Prediction

Library research

Some plants can reproduce new plants from a part of themselves.

Equipment and Materials

See text page 327; also the Teacher's Manual for Classroom Laboratory 6.

The cells in the offspring of only one parent will carry in its chromosomes (tiny bodies within the cell nucleus) determiners for the traits of the parent.

Introducing the Concept

What plant foods did you eat today? This question will at first seem to underline the obvious. But what about cereals, which perhaps only the more alert pupils will mention? Did you eat pie or cake, or drink a glass of ginger ale? Which plant foods are grown from seeds? Which usually in another way? (Potatoes, apples, and some other fruits by grafting.) Why are these two methods used? Accept, for the moment, any reasons offered; but suggest that seed catalogs and books about plants may provide an answer.

Hold up a piece of potato with only one "eye." Could you grow a new potato from just this much of one? What kind of potato would you get? Will it be the same or different from the parent plant? If you plant a seed, do you always know what kind of plant to expect? Red flowers or white? Tall plant or short? Again withhold comment, but permit forming of hypotheses which will be explored in this and the following section.

Is heredity more important than environment in the development of a plant? Is this also true for an animal?

Developing the Concept

New plants from one parent. The investigation on page 327 will, of course, require ten days to two weeks to produce sufficiently visible results. Hence, as the investigation is planned, use the illustrations on page 326 and the text opposite to aid pupils to form hypotheses their investigation will test a few weeks later. What does a new potato plant need to supply it energy to grow through the soil? (Starch.) Which simple test demonstrates that a potato contains starch? (Iodine solution turns starch a bluish black.) Several pupils may wish to demonstrate, using bits trimmed from the piece cut down to the "eye." By planting extra pieces of potato and digging up one each day, pupils can see the rate at which the energy supply is used by the growing plant. Keep all conditions the same for these pieces. Why do we use the same size for each piece planted in the investigation? Why do we trim one? (To have a control.) Be sure pupils recognize the purpose of the investigation is to determine the effect of the environment and not to grow potatoes! After the potatoes are planted, proceed to discussion of page 328 and formulation of hypotheses before pupils read page 329.

A potato's inheritance. Even with a microscope it is not easy to see the tiny nucleus in each potato cell. What still smaller parts found in the nucleus carry the traits? (Chromosomes.) What part of the chromosome seems to be responsible for each trait? (Genes.) Only by being enlarged 300,000 times by the electron microscope can genes be seen and studied. (Since the DNA molecule will be studied in Section 2, it is only necessary to bring out that each *individual* organism possesses traits.)

What traits can you name for potatoes? A produce man can supply samples of several varieties of potatoes. How do the traits compare? Are skin color and thickness, general size, shape, and weight about the

same? Which traits make potatoes good for baking? for mashing? Do you think these traits are the result of inheritance or environment?

Traits—inherited or acquired? Recall of the work done in Unit One may be beneficial. How did you learn to walk? Throw a ball? Read a book? Learn to study? Were you born with these abilities? Would you say inheritance or environment had the most influence in developing these traits? Since the potatoes have not yet poked through the ground in the investigation, what acquired traits do you think you will observe in your potato plants as a result of changes you made in the environment of each piece planted? If any pupil should say "Our book said so," encourage adoption of a wait-and-see attitude. One trial is not "proof." How could you write a formula for the concept showing that heredity and environment work together to produce the traits in an organism?

($H + E = O$; i.e., Heredity + Environment = Organism.)

New plants from two parents. This method of growing potatoes is preferred by professional potato growers because the new plants will have the characteristics of the parent plant and also because potato plants set very few seeds. Many foods you listed from your diet ("Introducing the Concept") cannot be grown in this manner; most food plants are grown from seeds.

Have the pupils study the diagram as they read and identify parts of a flower (text page 330). If possible, have available—or have pupils bring—flowers for observation of all the reproductive parts.

Pupils may draw the pistil, labeling it ♀, the conventional symbol for female parent; and one or more stamens, labeling them ♂, the symbol for male parent. How do these structures make possible inheritance of traits from two parents? (Pollination.)

The plant embryo. Split open a few whole peanuts or lima bean seeds. The beans open more easily if soaked overnight. At the base of the two fleshy halves, you can see the beginnings of a tiny plant. This is the embryo. What will the embryo grow into? How do you know? (Each new cell nucleus carries chromosomes from the parent plant.) Which part determines the traits? (Genes.) From your study of the potato, where do you think the embryo gets its energy to grow above ground? (From starch stored in the fleshy halves.) If you plant a number of peanut seeds, or lima bean seeds, will all the plants look pretty much alike? Let the children state their hypotheses in preparation for the next section.

Extending the Concept

Looking ahead—studying different seeds. Obtain a variety of seeds. The quick-growing type is to be preferred, such as radishes, beans, zinnias, marigolds, sunflowers. Note how the seeds differ in size, shape, and color. To test that an organism is the product of its heredity and environment, children may try growing seeds under different environmental conditions—different soils, differing amounts of light, different

Heredity and environment work together.

A seed plant is the product of a cell carrying traits from two parents.

Equipment and Materials

... flowers, such as jonquils, to show seed-forming parts

An embryo contains the beginnings of a new organism.

Equipment and Materials

- ... plant parts for vegetative propagation
- ... variety of seeds
- ... soil and containers
- ... pollen
- ... sugar

(Text pages 331–32)

(Text pages 332–35)

SUBCONCEPT

The DNA molecule carries in its parts (genes) the code that determines the inherited traits of an organism.

Processes emphasized

- Analysis of data
- Observation
- Measurement
- Library research
- Development of models
- Analysis of models
- Consultation with experts

amounts of water. This investigation will be useful as concepts are developed in later sections of the unit.

Vegetative propagation. Pupils might like to try different ways of getting new plants from one parent. Refer them to text page 332. Sweet potatoes or yams may be tried. A mint sprig roots easily, but the water should be changed every few days to prevent fouling. A pupil may demonstrate one of several methods of grafting.

Pollen. A pollen grain falling on a pistil grows a pollen tube, which extends to an egg cell in the ovary. This must happen for the egg to be fertilized so that a seed can form. One class grew pollen tubes from Easter lily pollen. They tried different solutions of sugar water until they found one in which the tubes grew large enough to be seen with the unaided eye. Your pupils may wish to devise a similar investigation.

Do all seed plants have the same number of seeds in the ovary? Is there any pattern in their arrangement? Is there any relationship between the number of petals or other flower parts? How many seeds come from an apple blossom? a lily? a sunflower? Direct observation where possible, coupled with library reference, makes an interesting investigation the source of a useful report.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. a 4. b 5. a 6. b 7. b

Using What You Know. 1. They use pieces containing at least one eye cut from the type of potato they harvest. 2. Pupil's hypothesis for later testing.

Section 2: INHERITING TRAITS

The pupils develop an initial understanding of how the coded information in the genes in the DNA molecule determines the traits of an organism. They learn that genes may be dominant or recessive for specific traits, and thus determine whether the traits will appear in a new organism.

Introducing the Concept

Suppose you planted seeds for red petunias and white petunias and dwarf zinnias and tall zinnias in your garden, carefully saved some of the seeds, and planted them the next year. Would you have all red petunias from the red-flowering plant and tall zinnias from the tall-flowering plant, or would you have other colors of petunias and perhaps some medium height zinnias? The chances are you would have quite a mixture. The following questions may encourage hypotheses: How is it possible to buy seeds for just one color and just one height? Are traits passed along separately? Do they remain separate or do they reappear as a blend of both parents? Do traits sort out so that you have some traits in one plant and some in another? How do you know what traits to expect?

For years these questions baffled scientists because they noticed that offspring sometimes resembled one parent, sometimes both, and sometimes neither. Then a curious Austrian monk, Gregor Mendel, had a hypothesis and a design for an experiment that had not been tried before. He would select *one* trait and study its appearance through several generations. He used his eyes and his knowledge of mathematics as tools, and his garden as a laboratory. Although he never saw a chromosome nor heard of genes, the laws of heredity he worked out still stand; he founded a new science.

What determines the hereditary code of an organism?

As the pupils read the text of the section, encourage them to relate it to the hypotheses they may have formulated above and at the end of Section 1.

Developing the Concept

Mendel's hypothesis and design. The story of Mendel's work as it is presented in the text offers a good opportunity for reviewing the methods by which scientists arrive at concepts (see, in review, Section 5 of Unit by which scientists arrive at concepts (see, in review, Section 5 of Unit One). What do you suppose Mendel's hypothesis was? (Perhaps—a single trait is passed on to the offspring.) What was his design for the experiment? (Find one trait and cross it with the opposite trait to see if half the plants will have one trait and half the other.) What were his results? (All one trait—tallness.) How might Mendel have restated his hypothesis? (When opposite traits are crossed in a plant, the dominant one appears in the offspring.) Some pupils may think that Mendel's new hypothesis might be that the dominant trait is the only trait inherited. How do you think Mendel went about testing this new hypothesis? What would you have done? Let the pupils think about this question, which you will explore more fully in the next section.

Three terms are important: *pure*, *dominant*, and *recessive*. Some pupils may be aided by the derivation from the Latin verbs *recedere*, to recede or withdraw, and *dominare*, to dominate or stand out. How do these meanings apply to recessive and dominant genes?

"The mind prepared." Again, in Gregor Mendel, we see how concepts come to the mind prepared. Mendel had broad training in mathematics and biology for his time. Were these abilities inherited or acquired traits? In the next section, you will see how mathematics came to Mendel's aid in his working out of the laws of inheritance. Do you think his concepts of dominance and recessive apply to animals? For example, what is the difference between a pure-bred (pedigreed) dog and a mongrel?

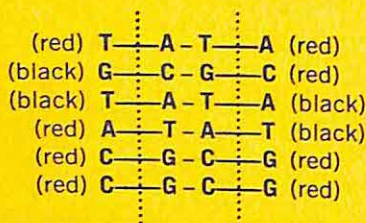
The DNA molecule. What is the DNA molecule? It is a compound of carbon, hydrogen, oxygen, nitrogen, and phosphorus. Pupils who recall previous work in science may recognize these as the elements that are found in proteins. Scientists believe that DNA is a large protein molecule with literally thousands of atoms arranged in different ways. There seem to be four different main groups containing nitrogen, carbon, hy-

Genes carrying the genetic code for a trait may be either dominant or recessive.

The genetic code is carried by a large molecule in the chromosome

Equipment and Materials

... at least 20 oblong blocks



drogen, and oxygen atoms. Attached to these four groups are two other kinds of groups. A simplified model can convey to your pupils an initial concept of the DNA molecule and how it carries the genetic code for traits. Twenty or more oblong blocks (the more, the better) can be marked alternately at each end C—G, G—C, A—T, T—A. The first four can be marked in black, the next four in red, and the next four in black, and so on until all your blocks are marked. Now scramble the blocks as you would a box of dominoes. Make two stacks in the following manner: Select a block at random from the pile. Let us say it is T—A. Select another T—A from the pile and place it next to the first, so that the arrangement is T—A—T—A. Do not attempt to match colors—only letters. Now select another block (it doesn't matter which), pile it on the first block, and match it in the second pile. When you have used all the blocks, they may look somewhat like the stacks of letters in the margin. You have models of *two* DNA molecules.

Now let's use our imaginations. Suppose we cut each pile down the middle and match the letters that are next to each other. You have a new model of a DNA molecule, but the color codes are different. Imagine that red is dominant and the black is recessive. Can you see how the traits that will appear in the offspring may be different? Once pupils catch on to the model, they may enjoy building it up, scrambling the blocks, and building up another model. Black and red crayons can be used for recording on separate sheets of paper the original patterns and the resulting patterns, if you wish. Pupils, however, should soon infer from model-building that some traits are likely to be dominant and others recessive whenever they are passed from parents to offspring. *The actual process of the genetic code is far more complex than the model indicates.*

Fruit fly heredity. Pupils may ask about fruit flies (page 334). Why use them? A fruit fly generation requires about 12 days, while plants require a whole growing season. The fruit fly has only four pairs of chromosomes in its cells; plants have many more, varying with the kind of plant. The nucleus in each of your cells has 23 pairs of chromosomes; one kind of butterfly has about 380. The fewer the number of possible chromosome combinations there are, the easier it is to follow traits and chart the offspring.

Extending the Concept

A report on Gregor Mendel. Interested children may wish to find out more about this founder of the science of genetics. Why did his concepts go unrecognized so long? How have they become increasingly important in the control of disease? Can certain diseases, or a tendency toward them, be inherited? Books in the school library and on the science reading table should be consulted.

What is meant by a pedigreed animal? Purebred stock has been recognized and prized for thousands of years. Why does a pedigreed dog cost more than a mutt? How do nurserymen develop a new strain of plant?

How do animal breeders make use of the science of genetics? A plant or animal breeder may be willing to visit the class or talk with a committee of pupils.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a 5. b 6. a 7. a

Using What You Know. 1. Black; the dominant trait appears in the offspring. 2. Shorthorned; because shortness of horns is dominant.

Section 3: CROSSING PLANTS

The pupils gain understanding of how plant breeders control inheritance of desired traits by insuring that only genes pure for that trait are passed from parent plants to offspring.

Introducing the Concept

Recall that in Section 2, the pupils studied Mendel's crossing of pure tall and short pea plants, and that only tall plants were produced in the next generation. Were all these pea plants pure for tallness? Did shortness disappear? Encouraging a questioning attitude: How could we find out? A helpful model, which may be most time-saving to have ready in advance, is to prepare enough small opaque bags, placing in each 12 green peas and 12 yellow peas. Explain to the class that you have "crossed" two kinds of pea plants that are pure for a certain trait, and that you have used yellow pea seeds for a dominant trait and green seeds for a recessive trait. Let pupils work in pairs, each pair with two bags of seeds. One pupil draws one seed from each bag, while his partner writes down each pair of seeds drawn under headings YELLOW, MIXED, GREEN. No peeking in the bags allowed! After all the seeds have been withdrawn, set the totals of the groups on the board and add them up. What do we find? (About half are still mixed; one quarter are green; one quarter are yellow.) This is actually what Mendel found when he planted his crossed tall peas. They sorted out—three tall plants and one short on the average. But later experiments showed that one of the three tall plants was pure for tallness.

How would you go about finding out if a plant was pure for a trait? How would you make use of your findings to get only pure plants?

Developing the Concept

Crossing plants for color. As the pupils read the text of pages 336–37, encourage their relating what they read to the model investigation under "Introducing the Concept." What is meant by *pure* breed or *pure* strain? How can plant producers be sure of producing pure plants? How is control of pollination useful? What are the procedures used in control? Why

(Text page 335)

(Text pages 336–41)

SUBCONCEPT

Organisms can be maintained genetically pure for a given trait.

Processes emphasized

Development of mathematical models
Analysis of models
Investigation
Analysis of data
Hypothesizing
Theorizing
Prediction
Library research

Equipment and Materials

... green and yellow pea seeds
... paper bags (opaque)

A pure trait can be kept pure by making sure that seeds have genes for only the pure trait.

Selecting of traits can be controlled by selective pollination.

Equipment and Materials

... sweet pea or petunia flowers

Dominant and recessive traits can be sorted out by crossing.

are insects, wind, or hummingbirds a threat to the growing of a pure strain of a flower? After these questions have been discussed, the pupils are ready to consider the investigation on text pages 338-39.

Investigating cross-pollination. Each child, or group of children, should have, if possible, a petunia plant in flower to work with. A nurseryman may cooperate by contributing a flat of plants or making a special price. If there are six classes, obviously he should not be expected to contribute his work free. Encourage careful techniques: In doing this investigation, you are surgeons performing a delicate operation. At each step, stop for clarification of such questions as these: Why were all the stamens cut from the white petunia plant? (The illustrations are useful to follow if the season is not right for obtaining petunia plants.) Why is a plastic bag placed over the white petunia? How did the white petunia blossom get "red" pollen? Why was the plastic bag put on again?

Some pupils may wish to carry the investigation further, care for the plants until seeds have set, and plant the seeds in a garden and note results. This will require time, patience, and considerable care. It may even result in failure, but other learnings may be a useful by-product.

Breeding plants pure for a trait. Pupils should study carefully the diagram on page 340 as they read the text. How do the results of crossing plants pure for white flowers with plants pure for red flowers compare with Mendel's experiment with tallness and shortness? How do the symbols show that the flowers of the first generation will always be red? Would it ever be possible to get white flowers from red-flowering plants? Why? (If two red-flowering plants have a dominant gene and a recessive gene and the flowers are crosspollinated, it is possible for two recessive genes to appear in the seed [egg cell]. For example, $Rw \times Rw$ might result in RR , Rw , or ww .) As a thought question, you might ask: Why has no one grown a blue daffodil? (The gene for blueness has not yet appeared in daffodils—either as dominant or recessive.)

Extending the Concept

Your own heredity. Pupils are always interested in inheritance of traits as evidenced by such questions as: Why am I a boy (or girl); why do I have freckles, or red hair, or blue eyes? These are normal questions, but some should be approached with care as a class project. Sometimes children do not know they are adopted, or they may come from broken homes, or are orphans living with relatives or guardians. Whether to encourage exploration of personal inherited characteristics depends on your knowledge of the class and backgrounds of the pupils in it. One activity that is often of interest is the PTC paper test. About three out of ten persons are unable to taste the paper as salt, sour, bitter, or sweet. For details, see pages 191-92 of *A Sourcebook for the Biological Sciences*.

Flowering plants. Do all green plants have flowers with pistils and stamens? (Ferns do not, for example.) Are the structures similar in flowering plants in number, size, and location? Encourage children to watch

for and study inconspicuous flowers on trees—such as the maple or holly, larger flowers on the tulip tree, or odd flowers (catkins) on the willows and birches. Are the white “petals” on a dogwood part of the flower? (No; they are merely showy leaves—sepals—without chlorophyll.) Children can investigate many flowers at firsthand; it may become a hobby for some.

Plant-insect partnerships. Children who live in desert regions may have an opportunity to study firsthand the partnership between the yucca flower and the yucca moth. Other strange partnerships can be located in library references and then studied perhaps firsthand, depending on the region in which the pupils live.

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. a 4. b

Using What You Know. 1. a. In order to breed cattle having the traits he desires. b. A good environment will enable the traits to develop faster and better. If the environment is poor, the cattle may grow slowly and put on less weight. The cattleman is interested in getting the most beef from his herd and the best prices for it in the shortest time. 2. Mongrels may carry undesirable recessive genes that may show up in the offspring if the same recessive gene is passed on by each parent.

Section 4: BLENDING TRAITS

Pupils develop a deeper understanding of the concept of inheritance of traits by studying the effect produced in the offspring by genes that are neither dominant nor recessive; when two traits are carried by the cells in the offspring, the offspring is a hybrid.

Introducing the Concept

Suppose you cross a white and a red four-o'clock, what color do you think the offspring will be, on the basis of what you have studied so far? (The offspring will be either red or white, depending on which is dominant.) But you get a pink flower! Or, suppose a white dog and a black dog are crossed, and you get a spotted dog, what hypothesis would you suggest? Was Mendel wrong? Perhaps the pupils may suggest that somehow the genes reached a *compromise* or that the colors *blended* to produce in some way a visible effect. (Of course the colors in the four-o'clock do *not* blend; the genes have interacted, and the effect is pink.)

Have you ever heard of hybrids? What is a hybrid? Can two traits be dominant in the same organism at the same time and produce an effect like neither trait, but yet a combination of both?

Refer pupils to the text of the section. Follow up reading with general discussion.

(Text page 341)

(Text pages 342–46)

SUBCONCEPT

Genetic traits interact in many ways; the resulting effect may be dominance, recessiveness, or blending.

Processes emphasized

Analysis of data
Development of mathematical models
Hypothesizing
Theorizing
Prediction
Library research
Discussion

Developing the Concept

Two ways of showing hybridization. Use a flannel board with R and W cards or tagboard labels, or arrange them on the desk. R will cross with W and W will cross with R . (R is for red-flowering and W is for white-flowering.) The plants will all be RW —neither dominant or recessive. Now suppose you cross R with w (recall that a capital letter stands for a dominant), what will you get for traits in the offspring? (All R —the dominant trait.) Obviously, you are crossing red-flowering plants with white-flowering plants in both instances; but what would you suspect would be the apparent color of the RW plants, where the interaction of R and W genes produces blending? (The effect is pink.) We note that RW turns out to be pink and that Rw turns out to be red, the trait of the dominant gene. *The pattern of sorting is the same. The effect is different.* This tagboard or flannel-board modeling should permit pupils to infer that there are *two kinds of hybrids*—one in which a trait is *dominant*, and the other in which the traits are *blended* in their effects.

Your pupils may wish to try out other combinations. For example, blue eyes are considered to be recessive and brown eyes dominant. How do you explain the fact that a child may have hazel or olive colored eyes? Let pupils assign symbols for each trait (as BL and BR) and work out the combinations. Or assume straight hair (S) is dominant and curly (c) is recessive; is it possible to have “half-curly” hair? (A word of caution: It so happens that in certain apparently common traits, several traits may be linked together. A tall plant may have flowers only at the end of the stalk or at the juncture of the leaf with the stalk; baldness in men is also considered to be linked to the trait of maleness. In other words, two or more traits sometimes are passed along in tandem, so to speak, and the combined effect is multiplied in complexity.) A pupil who is inclined to see a concept as “all black or all white” should be urged to consult references and adopt a wait-and-see attitude.

Traits and technology. Can you change some traits? Many persons have straight hair, for example. Most men normally grow hair on their face. Can a person ever have curly hair after many visits to the hairdresser? Or does shaving eventually mean that a man will not have hair on his face? The pupils may consider these questions ridiculous, but their ridicule of the ridiculous may serve to point up the fact that certain traits cannot be changed—only the outward appearance. To stress the point that the effect of genes cannot be altered, you may wish to tell the pupils of August Weismann’s experiments with mice. As you probably know, he was interested in finding out whether acquired traits could be inherited. He cut off the tails of young mice and mated the bobtailed mice; the offspring had tails. He continued this procedure for many mice generations. The offspring still had tails. See if your pupils can draw the correct inference that traits in the chromosomes cannot be altered unless the chromosomes (the DNA code, actually) are altered. Perhaps a review of the DNA model (page T-162) will be useful.

When two different genes affecting the same trait are in the chromosome (or the DNA molecule), the organism is a hybrid.

The visible appearance of traits may be altered, but the traits remain unchanged.

Extending the Concept

Chance discoveries. A New England farmer, Seth Wright, had to erect high fences to keep his sheep in pasture. One day he found a short-legged lamb in his flock of sheep. He had an exciting idea: what if he could breed sheep with short legs so that he would not have to spend so much money and time in building high fences? How do you think Farmer Wright went about trying to develop a new breed of sheep? Look up in library references the story of what he did and report on it to the class.

Explain the relationship of Wright's discovery to dominant and recessive genes, if you can. There are other stories of breeding to obtain desired traits—hornless cows, cattle resistant to disease carried by insects, small turkeys with heavy meat, corn with more kernels to the ear, and so on. Interested pupils can start library research, which will enable them to make contributions in later sections, to make clearer the central concept that the characteristics of a living thing are laid down in a genetic code. Reports on chance discoveries anticipate the work on mutations in Section 5. Interested pupils—and usually those who are beginning to show a commitment to science—will be able, by their contributions, to help other pupils develop insight into concept relationships of increasing complexity. All pupils should benefit from sharing of ideas and experiences.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a 5. a

Using What You Know. 1. (Sample answers .) A mule is stronger than either the mare (female horse) or the donkey male, of which it is the offspring. Hybrid corn has more kernels to the ear and may have longer ears than either parent. 2. Both traits in the parent are good traits; when neither is dominant, but blended, in the offspring, the advantages of both traits are combined in a "prize package."

Section 5: CHANGING THE CODE

NOTE. This and the following section serve the Conceptual Scheme:
Living things are in constant change.

The pupils extend their understanding of the concept that new traits appear as the result of a chance change in the genes (the DNA code), and that these changes can be inherited.

Introducing the Concept

Exhibit pictures of an orange or a bunch of grapes, a cow with long horns, and a daffodil. (Other pictures can be used if you adapt the fol-

(Text pages 345–46)

(Text pages 346–54)

CONCEPT (Sections 5 and 6)
Changes in the genetic code produce changes in living things.

SUBCONCEPT
The genetic code can change.

Processes emphasized

Observation
Analysis of observations
Analysis of mathematical models
Library research
Hypothesizing
Theorizing
Prediction
Reporting

A mutation (a change in the gene)
is passed along in the genetic code.

Equipment and Materials

... seedless (navel) orange
... seeded (Valencia) orange

Offspring of a single parent have
the parent's genetic code.

lowing introductory questions.) Which would you rather eat, an orange (or grapes) with or without seeds? Would you like to go near a cow with horns like these? Would you be excited to find a blue daffodil if you were raising plants in a nursery? Oranges and grapes used to have seeds; now we can buy them without seeds. Cows used to have long horns; now many cows never grow horns. There is no such thing as a blue daffodil, but it would be an exciting discovery and very profitable to anyone who found one and could grow more of them. Have you ever seen a white robin or a white squirrel? They do exist; they are called albinos. How do you think seedlessness, hornlessness, changes in coloring might happen?

What causes new traits to appear? How do plant and animal breeders make use of such chance changes? Are all such changes useful?

Developing the Concept

Usefulness of mutations. After the pupils have read text pages 346-47, make certain they understand the terms *mutant gene* and *mutant*. The former refers to the part of the DNA molecule that carries the trait; the latter is the term used to describe the organism that has a trait different from the normal. Which is the mutant, a seedless orange or one with seeds? Why? (A seedless plant cannot reproduce itself.) Why would a grower want to raise seedless oranges? Obtain a navel (seedless) orange and a Valencia (seeded) orange that weigh about the same, if both are available at the market. Remove the seeds and weigh them separately. What advantages do you see in a seedless orange, other things being equal? (Probably more pulp and juice; hence probably a better price on the market.) Raise the question for hypothesizing: How can you get more of a plant if it has no seeds? How can you raise more cattle—with short horns or no horns, for example—if almost every animal you have seen has long horns? Would cutting off the horns enough times give you animals that would never grow horns?

Propagation by grafting. Several groups of pupils working together may perform the investigation on text page 349, so that all may have firsthand experience with the method. Encourage careful techniques: This is a surgical operation! If interested pupils have been investigating vegetative propagation (See Section 1, page T-160), they may be asked to report at this time. Several questions relating to the investigation may also be explored. Why must the branch and the stock tree be closely related? (Cell structure of unrelated organisms differs.) Will the grafted branch eventually change to be like the stock tree? (No, although some may think so. Sometimes the stock tree may grow suckers that crowd out the graft. Actually in propagation of new plants, the graft is made on the stem close to or below ground level and any suckers that grow from the stock are carefully removed.)

Pupils may be interested in the apple tree that bears five kinds of fruit. How is this possible? (Five grafts.) Why would this kind of tree be de-

sirable for a small area? (You could grow pie apples, eating apples, long-keeping apples, apples for apple sauce, and apples for cider—for example—all on one tree.) Is this the same kind of grafting as that in the investigation? If the pupils understand that the five different apples grow from branches attached to a single trunk, they will infer that the grafts cannot be made at the root. The process is known as budding. If interested students have been investigating vegetative propagation, they may be prepared to explain or demonstrate the method.

A pure herd from mutants. Why is it easier to reproduce plant mutants than it is to reproduce animal mutants? Pupils should readily infer that plant mutants can be grafted but animals must have two parents. How can you get more animals with the mutant trait? What did we find out when we studied Mendel's work? Pupils should infer that mutant animals must be crossed to obtain a hybrid. If the trait does not appear in the hybrid, does this mean that the trait was not passed on to the offspring? Again pupils should infer that the mutant gene is recessive and that breeding the hybrids may produce a few animals that are pure for the recessive trait. What then happens if the animals with only the recessive genes in their genetic code are crossed? Can you now explain how cattlemen were able to produce a pure breed of shorthorn cattle?

If interested students are looking up other changes, such as Seth Wright's sheep (see page T-167), they may report what they have found out to add additional evidence on how mutations are preserved.

Can we change the genetic code? Why did the Nobel prize winner, Dr. Herman Muller, choose fruit flies for his investigation? Pupils recall, from Section 2, that fruit flies have only four pairs of chromosomes and that their generation span is only 12 days. If the investigation on page 351 is set up as a class project, a variety of traits will be seen within a short time. What change in conditions did Dr. Muller introduce that you haven't in your investigation? (Radiation.) Would you say this was a change in the environment of the fruit flies? (Yes; a drastic enough change to affect the DNA molecule in their chromosomes.) This, of course, does not imply that there were periods of extreme radiation in the past that caused many mutations; but Muller's work did show that mutations could be passed on through many generations of fruit flies, and that many mutations are unfavorable to survival. Dr. Muller's own description of the mutations he observed may be read to the class:

"All types of mutations, large and small, ugly and beautiful, burst upon the gaze. Flies with bulging eyes or with flat or dented eyes; flies with white, purple, yellow, or brown eyes; flies with curly hair, with ruffled hair, with parted hair, with fine and with coarse hair, and bald flies; flies with swollen antennae, or extra antennae, or legs in place of antennae; flies with broad wings, with narrow wings, with upturned wings, with outstretched wings, with truncated wings, with split wings, with spotted wings, with bloated wings, and with virtually no wings at all. Big flies and little ones, dark ones and light ones, active and sluggish

Offspring of two parents inherit genes from both parents; an increase in the number of mutants depends on interaction of the genetic code from both parents.

A living thing is the product of its heredity and environment.

Equipment and Materials

See text page 351; also the Teacher's Manual for Classroom Laboratory 6.

ones, fertile and sterile ones, long-lived and short-lived ones. Flies that preferred to stay on the ground, flies that did not care about the light, flies with a mixture of sex characters, flies that were especially sensitive to warm weather. They were a motley throng. What had been done? The roots of life—the genes—had indeed been struck, and had yielded.”*

Which of these mutations might not be useful to the fruit fly? (They are adapted to life in a particular environment; without wings, for example, they could not fly to their food.) If a mutant gene appeared that was dominant, what effect would this have on an animal's survival? Could it be a bad trait? If the environment changed, and no mutations favorable to survival in the new environment appeared, what might happen to the organism? Do your hypotheses help you to explain the development of the horse and the dying out of the dinosaurs referred to on text pages 352–53?

Extending the Concept

Reports. Space travelers will have to pass through a belt of strong radiation around the earth. How do you think Dr. Muller's work in radiation genetics is of interest to researchers in space medicine?

Can mutations be produced by chemical changes? Mustard gas has been used recently to produce changes in fruit flies, viruses, and in some molds and bacteria. One such mutation is red-spored bread mold, which you may have found if you have grown mold colonies on bread. A suggested source of reference is *All About Heredity* by Judith Randal, pages 108 ff. (see page T-156). A librarian can help you find other sources for reports in this interesting area of genetics.

Some diseases are the result of undesirable genes. Hemophilia, or bleeder's disease, is a sex-linked characteristic that is recessive in women, but may appear in males. Interested pupils may wish to look up this disease and report on its causes and treatment. The tendency to some forms of diabetes is known to be inherited. The disease may appear in the offspring under certain conditions. It is a result of the inability of the pancreas to produce enough insulin, a secretion that helps the body oxidize sugars. The disease cannot be cured, but it can be controlled. Pupils may investigate the methods and current research.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a 5. a 6. a

Using What You Know. 1. By mutation; also, if red is dominant, other colors may be recessive and pure traits; colors may be blends. 2. Mutations occurred that better adapted the horse to his environment; for example, a hoof may have given greater speed for evading enemies. The less well adapted tended to die out.

* From the *Scientific Monthly*, December 1929, quoted with permission.

Section 6: THE SEARCH FOR PRIZE GENES

The pupils follow several applications of the concepts of heredity in the breeding of plants and animals. They find that in genetics, as in other areas, the scientist and technologist work together.

Introducing the Concept

Have you ever been to a county fair or a plant show? If not, perhaps you have watched a horse show or a dog show on television. Blue ribbons, a silver bowl, or even a prize of money is awarded to the best flower, the best animal of a breed, or the best in show. What do you think the judges look for? A pupil who has seen any plant or animal show, either at firsthand or on television, can describe what he has seen. Would you say that the judge was looking for prize genes? (Yes.) But is this all? Pupils should infer that some traits are acquired. Which are likely to have been inherited traits? (Shape, color, size in relation to the breed, distribution of parts of the organism, and so on.) Which are acquired? (Various skills of animals; size and weight, sometimes; general grooming of animals, etc.)

If you happen to have an interest in horses, dogs, or other animals, you may have photographs. These may be displayed where the pupils can view them readily. Let the pupils act as judges and vote for the best animal and defend their choices as above.

How do plant and animal breeders select and maintain desirable traits?

Developing the Concept

Prize genes in animals. Since this entire section describes applications of concepts of heredity, which the pupils have been studying throughout the unit, you may wish to recall man's use of his brain, studied in Units Two and Three. How is a plant or animal breeder like a technologist who works with metals? When a metallurgist tries to find a new alloy, what is he looking for? (New properties.) When a plant or animal breeder tries to improve plants or animals, what is he looking for? (New genes.)

How does the breeder of animals apply concepts of heredity? As pupils discuss the search for the prize gene of hornlessness and the story of Monkey, they should understand how a mutant gene is tested, how a "registered" breed is developed, what the term *registered* means, and whether any genes make the organism better adapted to its environment. For example, how is the Santa Gertrudis breed of cattle adapted to the climate of Texas?

Prize genes in plants. How does the plant grower apply concepts of heredity? Pupils should show they understand the concepts of cross-pollination and the techniques for controlling the source of the pollen that falls on the stamens of the plant with the desired traits. Can there be a mutation in a plant that does not have seeds? Why not? Why is it

(Text pages 355-58)

SUBCONCEPT

Improved plants and animals are the product of selective breeding for the desired traits.

Processes emphasized

Library research

Analysis of data

Prediction

Desirable mutations in animals may be established by selective breeding.

Desirable mutations may be established by cross-pollination of plants having the desired traits.

especially important for a plant grower to provide the proper environment? Could he try to grow a new strain of cotton in New England or Wyoming? Could he improve a shade-loving plant by growing it in full sun? Could he lime his soil if the plant which has the mutant gene came from acid soil? Why not? (The environment must be one for which the plant is adapted.) Plants are not able to perform one life activity that animals perform. What is this life activity? (Moving about. A plant cannot move about to find the environment for which it is suited.)

Extending the Concept

Other prize traits. Would the desired traits for milk cattle be the same as those for beef cattle? What other prize traits might be desirable in cattle? One group of pupils divided into committees to study different breeds of cattle. For a while, they became experts and critical judges of drawings and models made by their classmates. If your pupils would like to study cattle, they may check for information with the nearest Federal, State, or County agricultural agent for the location of 4H Club centers and registered breeders associations. If possible, secure meat packers' charts of beef cuts to compare grade standards for specific cuts of beef.

More white meat . . . Turkeys used to weigh 24 pounds or more for the Thanksgiving dinner. Today, a 12-lb. turkey will give almost the same amount of meat, and especially an extra quantity of white meat. A government agricultural experiment station at Beltsville, Maryland, has succeeded in breeding turkeys, and other poultry, suitable for small ovens. Consult various references to find out more about poultry breeding. The annual *Yearbooks* of the United States Department of Agriculture are especially useful. They are available in many libraries.

. . . And bigger potatoes. What are the characteristics of the Katahdin potato that is raised in Maine? How did it get its name? (Find Mount Katahdin on a map of the state.) How was the strain produced? Seed catalog descriptions may list some of the characteristics of seed potatoes. Will you find seed potatoes in the seed section of the catalog or under another heading? Why?

. . . And better wheat. Wheat and other grain crops may be infected by fungi called rusts and smuts. If the whole cereal-raising belt across the United States and Canada were to become seriously infected with a fungus disease, how would many persons be affected? Make a list of all the workers who handle wheat in all of its forms. Do not forget the consumer! Or the animals as consumers! Farmers' seed catalogs describe different strains of resistant wheat, oats, and corn. Agricultural experiment stations in your state may be willing to provide information about experiments being conducted to develop improved varieties.

Reviewing the Concept

Using What You Know. Pupils' investigations and reports.

Section 7: THE MAIN CONCEPT: THE GENETIC CODE

As the pupils review how traits are inherited and how their development is influenced by the environment, they grow in awareness of the importance of providing the best conditions under which a trait may develop to its fullest capacity. Good inheritance is not enough; environment is not enough; both heredity and environment interact.

CONCEPT SUMMARY

The text of the section may be read before, or concurrently with, summarization of the concepts.

Hold up a coconut (or any other easily identifiable seed). What do you predict will grow from this seed? Why can you be so sure? Now, using a globe or a map, ask in what parts of the world the coconut tree might grow from the coconut seed. What kinds of conditions must it have? Clearly, the genes the seed has for becoming a coconut tree will not develop in all parts of the world.

Corn seeds have been treated with radiations so that the gene for making chlorophyll has been destroyed. Suppose you plant some of these seeds in an environment where corn plants have always grown well, and they come up and start to grow. What happens? Do the plants grow and develop into strong healthy plants? Clearly a good environment isn't enough then.

How many plant and animal products on the shelves or in the refrigerator at home are better than they were 100 years ago? (A visit to a supermarket with notebook and pencil would reveal a longer list—an interested pupil might volunteer to prepare such a list for discussion.) What reason can you give for these improved varieties? Here general discussion should bring out how Mendel's work in 1859 led to an understanding of the role of chromosomes, genes, and recently the DNA molecule in the transmission of traits from parent to offspring. Improved means of providing the most favorable environment for the hereditary traits to develop in should be mentioned. There may be debate as to whether heredity or environment played the greater role. Encourage it. The pupils are engaging in concept seeking.

Any children who are willing to bring family photographs to school should be encouraged to do so. It is best not to insist upon it, for some families have few or treasured photographs, some children may come from broken homes, or there may be other reasons. If a few sets of photographs are brought in, family likenesses may be examined by all the pupils. Does anyone want to tell some other way in which he is like another member of his family? Is this inherited or was it acquired because of some common interest that the parents had and encouraged in the children?

If some physical trait is mentioned, ask if another member of the family has this trait—a grandparent perhaps. What does this suggest about

(Text pages 359–63)

CONCEPTUAL SCHEMES

A living thing is the product of its heredity and its environment.

Living things are in constant change.

CONCEPTS

The characteristics of a living thing are laid down in a genetic code.

Changes in the genetic code produce changes in living things.

Is heredity enough?

Is environment enough?

How can organisms with improved traits be developed?

How are children like their parents?

How are children in some ways different from their parents?

How have living things changed over the ages? How can this change be explained?

What large concepts have we learned from this unit?

(Text pages 362-63)

the trait? Is it likely to be dominant or recessive? College students today are 2 to 3 inches taller than their fathers. Is this greater height due to a change in heredity or better balanced diet (an environmental factor)?

If possible, have available from your science picture file, or from the library, illustrations of prehistoric animals, such as dinosaurs, in their prehistoric habitat. Do any of them resemble animals today? Lizards, insects, birds, perhaps? Do any of the plants resemble those living today? Grasses, ferns, perhaps? How are they different? How do you account for the differences in animals and plants?

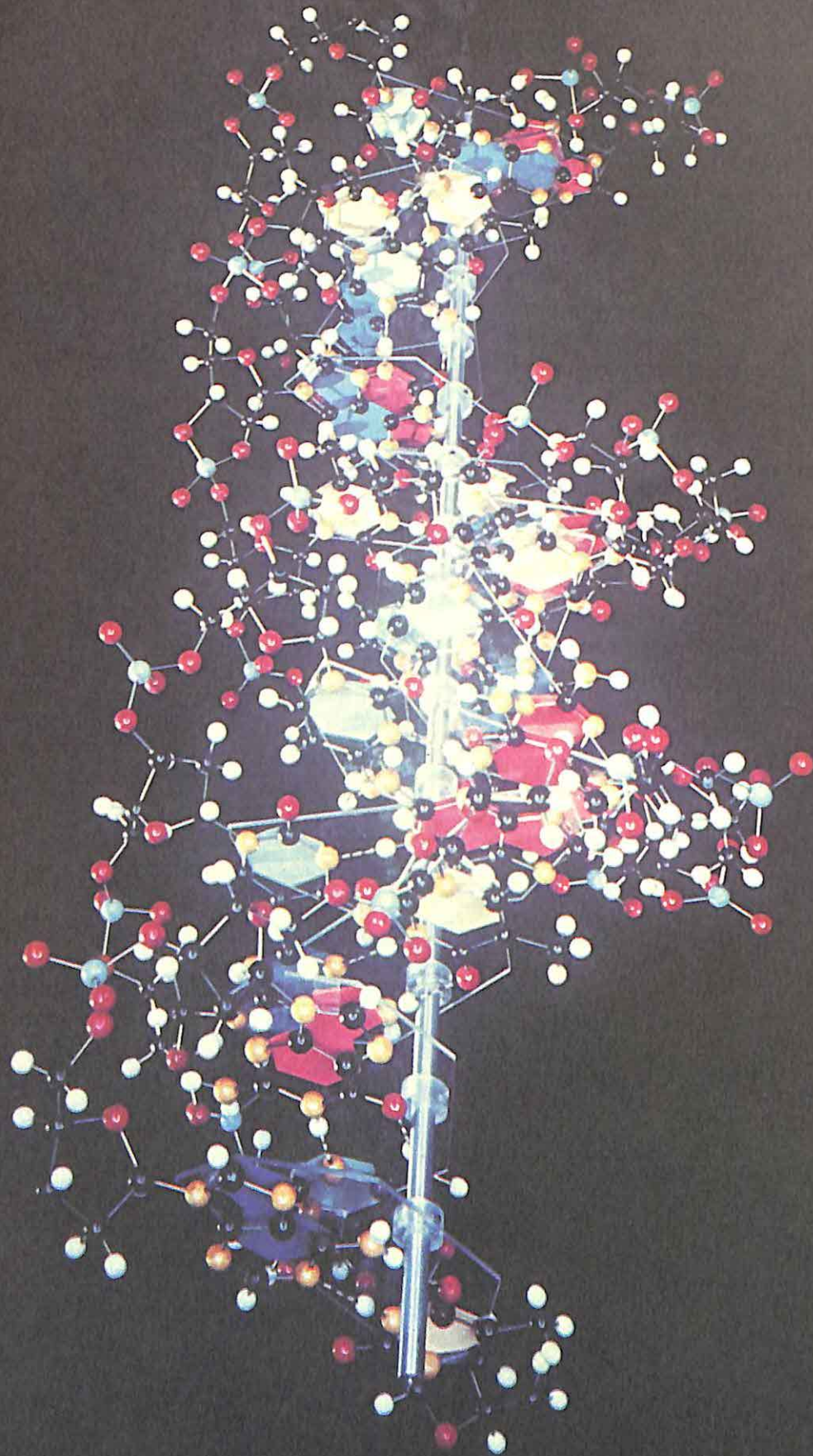
Let children formulate the concepts in their own words. They may also correctly infer that changes in the genetic code produce changes in living things. You may wish to have the pupils agree on the best statements. How are these concepts useful to us? Encourage each pupil to list a few traits he thinks he can improve and how he can go about doing so, thus reinforcing the importance of applying oneself to learning, which was first introduced in Unit One.

FIXING THE MAIN CONCEPTS

Testing Yourself. 1. b; traits are inherited through egg cells, not through blood cells. 2. b; fossils are different from animals now found on the earth, but similarities can be noted, too. 3. The plants must have been pure for the yellow-flowering trait. 4. The recessive gene for gray fur was carried by the black-furred hybrids. 5. Both parents had the recessive gene for blue eyes; the blue-eyed child is pure for the trait of blue eyes; one child *may* be pure for brown eyes and two hybrid; but all three brown-eyed children, or any of them, may be either pure for brown eyes or hybrid. 6. b

Quick Test. 1. b 2. a 3. b 4. b

TEACHER'S NOTES



UNIT EIGHT

CODE OF HEREDITY

Visit a ranch. The chromosomes in the nucleus of animal cells are responsible for the characteristics of the animals. Visit a farm. Both the plants and animals owe their characteristics to their chromosomes. Visit a market. The vegetables are a result of the plant breeder's art. Look in a mirror. Your chromosomes are largely responsible for the way you look and, in many ways, for the things you do. In fact, chromosomes are the link between one generation and the next, the reason that each kind of plant or animal produces its own kind. But that is not the whole story.

Long before man understood the concepts underlying heredity, he sought to improve the quality of each succeeding generation of plants and animals. He wanted plants that would produce more food on less land, cows that would produce more milk, chickens that would lay more eggs, cattle and hogs that would have more meat, and plants that would be resistant to disease.

In recent years, armed with more knowledge and techniques, man has applied new tools to old problems. Nowhere has science yielded knowledge of greater importance than in the study of chromosomes. A model of what scientists know about the structure of the chemical substance within the chromosomes is shown on the opposite page. This unit is only a beginning in the study of this substance—the basis of heredity.

1. A "Chip off the Old Block"

People sometimes refer to a son as a "chip off the old block," meaning that he is just like his father.

Actually, it is never true that a boy is just like his father or his mother. All boys and girls inherit traits from both parents. The word traits is used to mean many things—eye color, height, hair color, or even intelligence. All the traits that one inherits are called **heredity** (hə-red'ə-tē).

How important is heredity? Can we ever really say that a living thing is a "chip off the old block"? After all, living things that have two parents may inherit traits from each. With some living things, however, the expression "chip off the old block" may really fit.

Take a look at a living thing that starts life as a kind of "chip off the old block." You will make the "chips" yourself in the investigation on these two pages.

The Results and an Explanation

In several weeks you should begin to get results from your investigation. Do you find that:

1. the bud in the dark closet is pale and thin?
2. the bud which was not watered (after the first watering) has barely managed to sprout at all?
3. the bud with most of its food removed has barely come up and is thin and small?
4. the control is green with a stout stem and several leaves?

AN INVESTIGATION



into the Effect of Environment on Living Things

Needed: a large white potato with several eyes (buds); four small flower-pots; saucers; some garden soil

Divide your potato into four pieces so that each piece has an "eye." Each "eye" is a bud from which a new potato plant can grow.

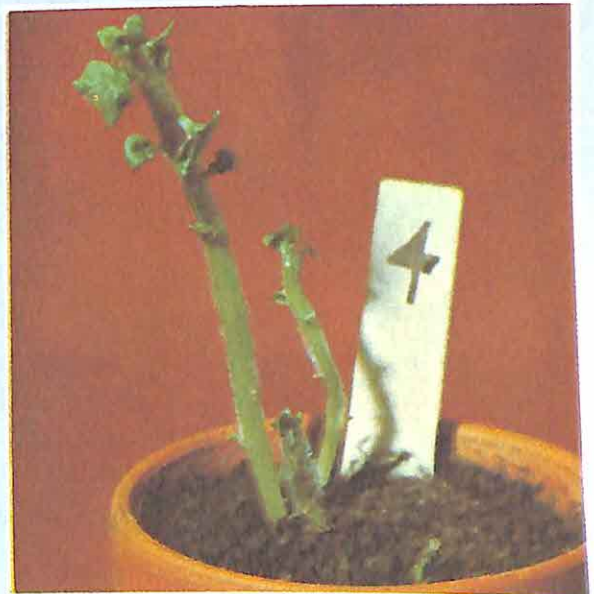
Try to divide the potato into four pieces of equal size so that each bud will have as large a piece of potato as the others. After you have done this, trim off almost all the potato from around *one* of the buds.

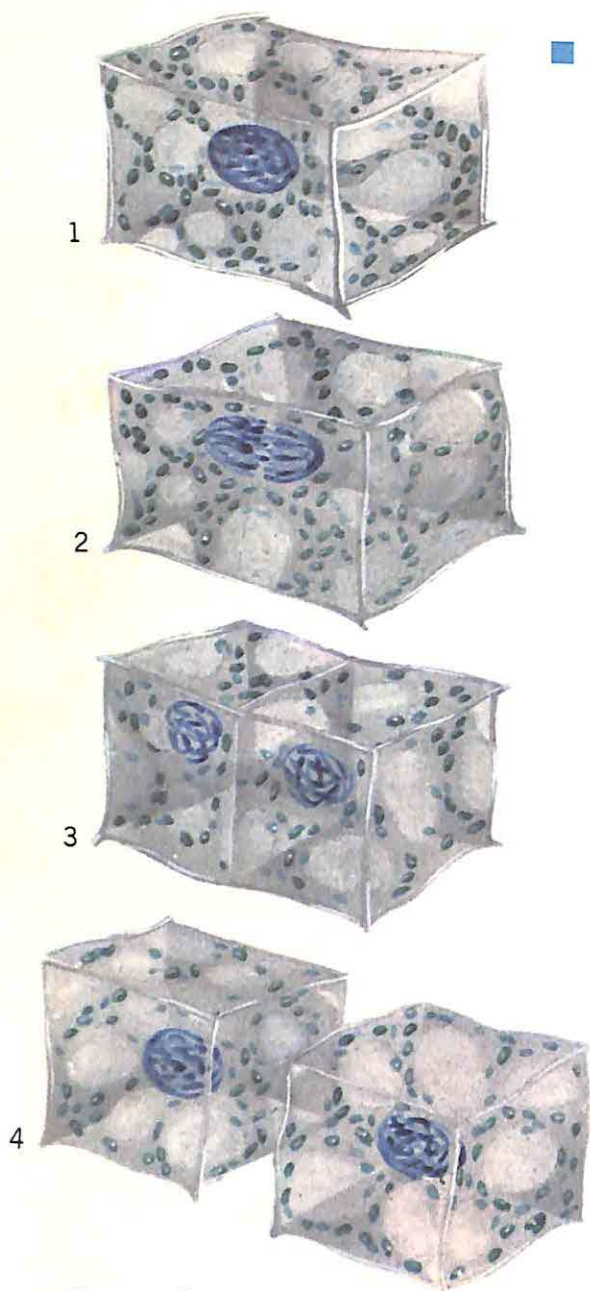
Now you have several "eyes" with good-sized pieces of potato around them. These untrimmed pieces have a great deal of starch in them. Starch is a food needed to supply the new plant with energy for growth.

One bud was trimmed so that it had only a little supply of starch around it.

Plant one piece of potato in the soil in each of the four pots. Plant the pieces with the eye *up* and water the soil, so that it is moist but not wet.

Place one of the pots containing a large piece of potato in a dark closet. Label this pot #1. ■ Place the other three pots where they will be in the light. Two of these have a large piece of potato. After the first watering, *do not* water *one* of the two pots again. Label this as your second pot. ● The third pot has the small piece of potato (with very little starch around the bud). ▲ The fourth pot (with a large piece of potato) is the control. ♦ All the others can be compared with this one. Keep the soil moist in the first, third, and fourth.





Remember that the control is the one which is to be compared with each of the others. Each of the other three plants lacked only one variable (light, water, or food supply). The control did not lack any variable.

How do you explain the results? All were pieces from the same potato. All were "chips off the same block."

Which of the four buds grew to look most like the parent plant? What causes a potato sprout to grow like its parent?

The bud of the potato is made up of cells. As it grows, the cells divide to make new cells. ■ Some of the cells form leaves, others form roots, and still others form the stem.

The potato plant that comes from the bud will be like the parent potato because of its **chromosomes** (krō'mə-sōmz). Chromosomes are found in the nucleus of a cell. They are usually rod-shaped but may be bent in different ways. The cells of the potato bud have the same chromosomes as the parent plant.

Each chromosome is made up of tiny parts called **genes** (jēnz), which are responsible for the traits of plants and animals. The new potato plant will look like the parent plant, because it has the same *genes* as the parent. Genes are the parts of the chromosome which carry the hereditary traits. The genes are believed to be parts of a huge molecule found within the chromosome. A model of a DNA molecule is shown on page 324.

All of the offspring of the potato plant will look like the parent—but *only if* the environment of the offspring is like the environment in which the parent grew.

The genes in the buds of the four pieces of potato were the same, but the environment in which each piece grew was very different. Therefore, the results were different.

One plant had no sunlight. The green substance in plants, **chlorophyll** (klôr'ə.fil), needs sunlight to develop. The ability of a plant to make chlorophyll is a trait inherited from the parent plant. This trait was there in the bud of the potato plant. Without sunlight, however, the genes responsible for making chlorophyll were unable to do their work.

One plant had little water. Without water the plant roots could not get substances they needed from the soil, and the plant could not make its own food. The genes which are responsible for growth in the plant could not work properly without water.

One plant had little food at the beginning of its growth. The genes responsible for growth were present in the potato bud, but the potato bud needed a food supply. Without it, the plant could not grow. The environment which would have supplied food for growth had been removed.

The explanation of the results is plain. A living thing needs a good environment in which to develop. Genes are not enough.

Without a good environment the genes in a seed may not fully develop their traits. The trait of "green color" shows up only when there is enough sunlight. The *ability* to produce chlorophyll is a trait transferred from the parent to the offspring in genes; but the *development* of the trait is determined by certain conditions in the environment. Sunlight is essential for the growth of green plants.

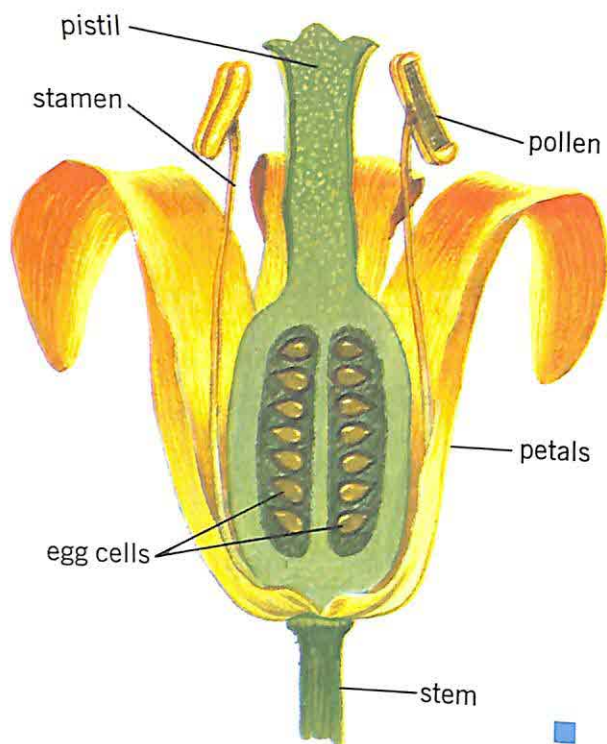
An oak tree is stunted when it grows in sandy soil without enough water. The trait for tallness in the oak is not developed unless the tree is growing in a good environment.

We come then to still another important concept: A living thing is a product of heredity acting together with the environment. In other words, heredity, acting in a certain environment, equals the organism.

This concept is true for all living things. Genes from parent plants are passed on to the offspring. You can cut off pieces from other plants, as you did with the potato, and plant them. The offspring are then very much like the parent—if the environment remains very similar.

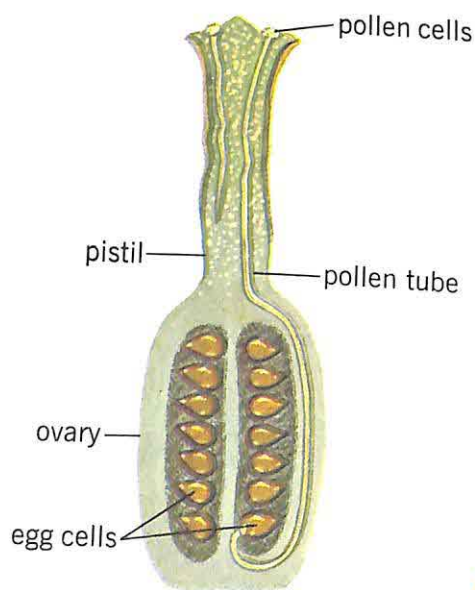
The young potato plants came from one parent plant. The genes in the offspring were therefore the same as in the one parent. This is not true of all new plants because some plants, like the tiny lima bean plant in the picture below, start from seeds which result from *two* parent cells. ●





Plants with Two Parents

Certain plants, the seed plants, have flowers. Cut apart a flower as shown in the diagram on this page and find the parts that are labeled. ■ A tulip or a pea flower will do nicely.



Before a seed can be formed, the flower must be **pollinated** (pol'ə-nāt-ed); **pollen** (pol'an) must fall on the **pistil** (pis'til). Tiny grains of pollen are produced by the **stamen** (stā-mən) of the flower. Each grain contains a living cell called a **sperm cell**. The grains of pollen are sometimes carried to the top of the pistil by the wind or by the feet of insects crawling around the flower. Sometimes pollen from the stamen of one flower is carried to the pistil of another. When the pollen grain lands on the pistil, it grows a long tube. ● This tube grows toward the **egg cell** (the part that later becomes the seed), at the base of the pistil. There the sperm cell from the pollen unites with the egg cell. The beginning of a new plant, the **embryo** (em'brē-ō), is produced. The embryonic plant (which is very small) stays in the seed until conditions, such as warmth and moisture, are right for it to grow.

The embryonic plants are so well protected within the seeds that they can survive a cold winter. In the spring, when it is warm and moist, they begin to grow. One or more seeds are formed in the **ovary** at the base of the pistil of each flower. The number of seeds is determined by the kind of flower. Number of seeds is a trait determined by heredity (genes).

In seed plants, the embryo gets chromosomes from *two* parent cells, the sperm cell and the egg cell. The genes in the two parent cells determine the traits of the new plant.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Chromosomes are generally found in
 - a. cells
 - b. genes
2. Genes are found in
 - a. chromosomes
 - b. chlorophyll
3. Inside the chromosome is a huge molecule known as
 - a. the DNA molecule
 - b. a pollen grain
4. The organism is the product of its heredity and its
 - a. genes
 - b. environment
5. A plant having only one parent may be reproduced from a part
 - a. of itself
 - b. of a seed
6. When pollination takes place, the pollen grows a long tube which enters the
 - a. stamen
 - b. pistil
7. A plant which develops from a seed is the product of
 - a. one parent
 - b. two parents

B. Write a paragraph or two on this topic: A "Chip off the Old Block."

**USING WHAT
YOU KNOW**

1. There are many varieties of potatoes, *Idaho*, *Katahdin*, and others. How can farmers be sure to get the same variety for re-planting as the ones they harvest?

2. The embryo in a seed inherits its traits from two parents. Suppose an embryo came from two parent plants—one was red-flowered, the other white-flowered. Into what kind of plant might the embryo grow?

- a. red-flowered?
- b. white-flowered?
- c. any other color?

What is the hypothesis behind your answer?

Some plants can reproduce themselves from their roots, stems, or leaves. The white potato, for instance, is a thick underground stem. Parts of the potato stem can grow into complete plants.

When a plant reproduces itself from its parts, the process is called *vegetative propagation* or sometimes *vegetative reproduction*. Perhaps you would like to see for yourself how vegetative propagation takes place in other plants. Below are two plants which you might want to investigate.

A carrot: its thick orange root will reproduce the entire plant. Plant it and see.

A willow: a twig will grow roots and leaves. (Try this in early spring.)

What other plants undergo vegetative propagation?

To find out, look in an encyclopedia. The answer may be found under any of these topics:

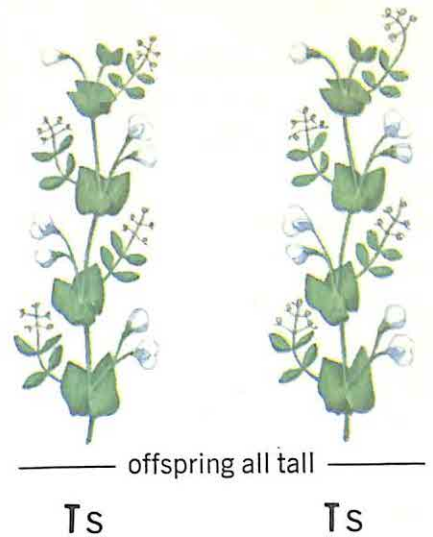
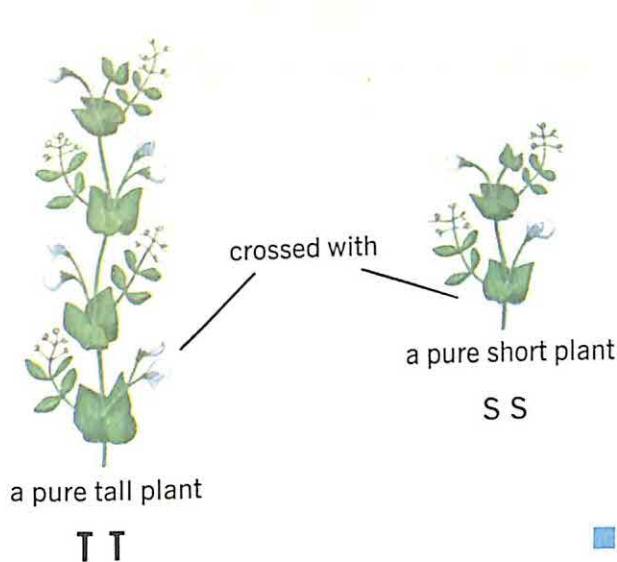
plant life	vegetative propagation
plant propagation	vegetative reproduction
	plants

2. Inheriting Traits

There are garden pea plants that grow tall and some that grow short. What happens when a tall pea plant is pollinated, or crossed, with a short pea plant? For the time being, let us say that a *pure tall plant* crossed with another *pure tall plant* can produce only *pure tall plants*. A *pure short plant* crossed with another *pure short plant* can produce only *pure short plants*. We call a plant **pure** when it has only the genes for a certain trait. For example, a pure tall plant has only genes for tallness. There are no genes for shortness in the plant.

Suppose one of these pure tall plants is crossed with a pure short plant. It can be done this way. Pollen, obtained from the stamen of a flower of one plant, a pure tall one, is placed on the pistil of a pure short plant.

A tall garden pea plant is now crossed with a short garden pea plant. What will the offspring be? Do you understand why? The gene for tallness is represented in the diagram by "T"; the gene for shortness by "s." ■ All the seeds that are produced will grow into tall plants. Although this is true of garden peas, it is not necessarily true when other kinds of plants are crossed.



Gregor Mendel, an Austrian monk and scientist, first investigated garden peas about 100 years ago. Whenever he crossed pure tall plants with pure short ones, he got offspring which were tall.

He called tallness a **dominant** trait. What does dominant mean? The gene for tallness *seems* to dominate or “rule over” the gene for shortness in garden peas. Mendel called shortness a **recessive** trait because it seems to disappear in the offspring. But the genes for shortness have not disappeared or been destroyed. They are still present in the new plant, the offspring, but only the dominant trait is apparent.

When Mendel crossed pure tall plants with pure short plants, he got only tall plants. Tallness was the dominant trait. The recessive trait (shortness), however, is also in the offspring.

Somehow tallness and shortness are passed on from the parent plants to the offspring.

The Message in Cells

Scientists think that chromosomes carry a kind of message from the parent to the offspring. You might think of the chromosomes as carrying a kind of *code*. What is a code? It is a shorthand way of giving information. For instance, here are a few lines of the Morse code.

```

/-/.../ /-.../.../ /-.../.../
-/.../ /-.../.../ /-.../.../
/.../.../ /-.../.../ /-.../.../
-/.../.../ /-.../.../

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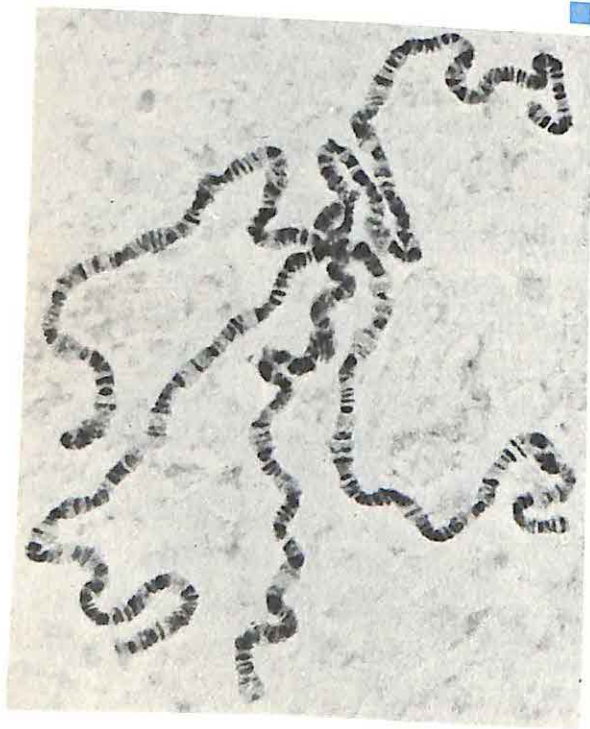
Translated it says:

The genes are the code of hereditary traits.

In every organism the genes in all the cells seem to be the same. They seem to duplicate themselves, so that the code is passed on every time the cell divides.

Scientists now believe that the genes are smaller parts of the large molecule called the **DNA molecule**, which was mentioned earlier. In fact, the chromosome contains the large molecule of DNA (short for deoxyribonucleic acid). The genes are thought to be smaller parts of the molecule. When scientists learn more about the nature of DNA, we will have a better understanding of genes. Perhaps they will be able to explain how the genes can determine hereditary traits.

Here is a diagram of the long chromosome of a fruit fly. Some of the tiny lines you see might be the genes for eye color, white eye color. ■ These genes are parts of the chromosome which carry the code for eye color. Each of the two genes was inherited from a different parent. One of the genes for white eye color came from



the fly's male parent. The other came from the female parent.

The code in the chromosome or in the long molecules of DNA directs the way a living thing develops. A plant which is pure for tallness carries the code which directs the plant to grow tall. The code in the chromosomes of a certain fruit fly acts on the cells to produce white eyes.

Genes do not act alone, however; the environment plays an important part. Without a good environment, a plant with genes for tallness would not grow as tall as it is capable of growing.

The *DNA code* (the code in the chromosomes) determines the traits; the *environment* helps in determining the development of the traits.

DNA molecules in a hen's cells carry the code which determines whether the hen's eggs will be brown or white. The long DNA molecule in the chromosomes of a red flower determine its red color.

Scientists do not know the whole story yet. They know that the chromosomes contain DNA and that this substance carries a kind of code. This code carries the information, in the genes, which determines which traits will develop.

Look again at the lines and shadings on the chromosome in the picture. Today scientists are not sure what each one stands for. Maybe sometime in the future they will be able to solve the code and solve one of the greatest mysteries of nature.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A pure tall plant crossed with a pure tall plant will produce
 - a. only tall plants
 - b. some short plants
2. A pure tall plant has at least two genes for tallness. One gene for tallness is received from
 - a. each of both parents
 - b. only one parent
3. When a pure tall garden pea plant is crossed with a pure short garden pea plant, all the offspring are
 - a. short
 - b. tall
4. In the garden pea, tallness is
 - a. dominant
 - b. recessive
5. The hereditary code of an organism is carried in its
 - a. environment
 - b. chromosomes
6. The hereditary code of an organism seems to be in the DNA. DNA is a
 - a. long molecule
 - b. dominant trait
7. DNA might be said to be the basis of an organism's
 - a. heredity
 - b. environment

B. Write a paragraph or two on this topic: DNA—The Code of Heredity.

**USING WHAT
YOU KNOW**

1. In guinea pigs the genes for black fur are dominant over the genes for white fur. A pure black-furred guinea pig is crossed with a pure white guinea pig. What kind of offspring would be produced? Why?
2. In cattle the genes for short horns are dominant over the genes for long horns. A pure shorthorned animal is crossed with a pure longhorned animal. What kind of offspring will be produced? Why?

3. Crossing Plants

Look at the picture and study the red- and white-flowering garden peas for a moment. ■

Farmers and plant growers are interested in the colors of the blossoms of garden pea plants, because they are linked with the color of the peas that grow later. White-flowering plants produce the bright green peas that most people buy and eat today. Red-flowering plants, on the other hand, produce a grayish-looking pea that tastes as good as the green pea but is not as attractive. Since the attractive-looking peas are easier to sell, it is natural that most farmers are only interested in obtaining seeds for the white-flowering plants.

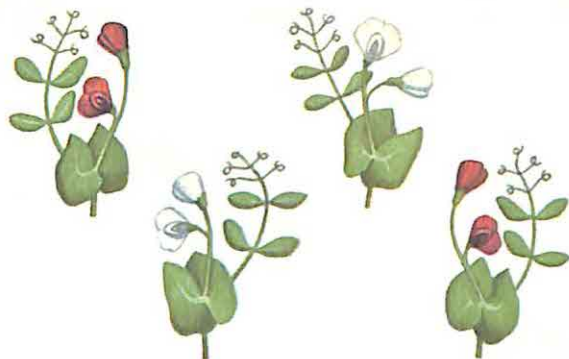
Now suppose you were a plant grower, interested in growing only

white-flowering garden peas, not red ones. You would want to be sure that your seeds produced only white-flowering plants, *not red ones*. How can you go about getting plants that will produce seeds which will grow into white-flowering plants only?

You might say that you would plant only the seeds that come from white-flowering plants. However, when you plant these seeds, you might be very much surprised. The plants coming from these seeds might produce *either* red *or* white flowers. ● Soon you will discover why.

This is a problem that plant growers are faced with all the time. They want to be sure that the seeds they sell in a seed packet will produce the plants shown on the label. If the label is to say "white-flowering," the plant grower wants to be sure that only





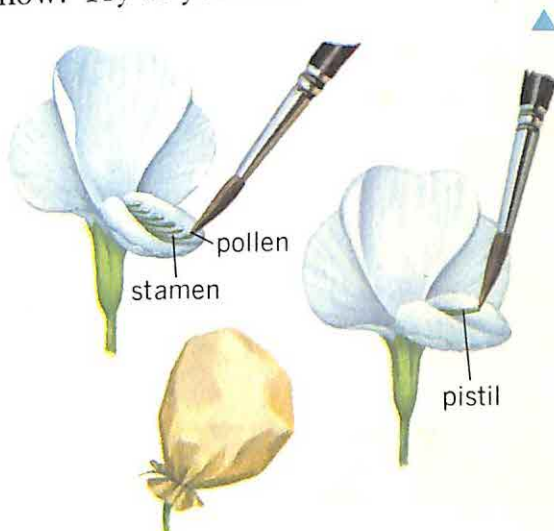
white-flowering pea plants will grow. If a consumer buys the seeds, he also expects to get what the label says.

Crossing Plants for Color

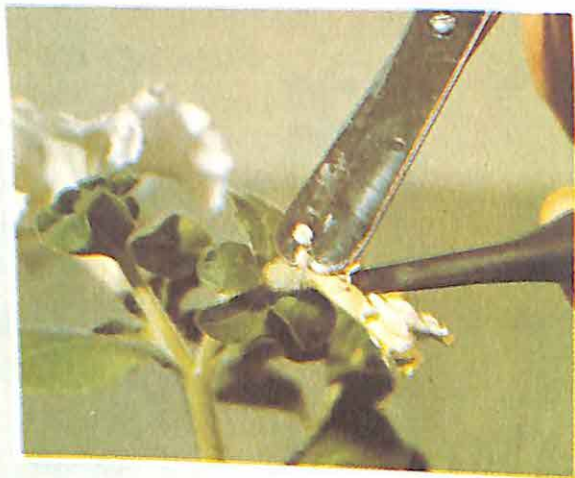
If the grower wants white-flowering plants, he starts with white-flowering plants. The seeds from the white-flowering plants may produce either red- or white-flowering plants. The reason for this is that a white-flowering plant may have been pollinated by a red-flowering plant.

The grower then makes sure that the white-flowering plants are crossed with other white-flowering plants. He takes the pollen of one white-flowering plant and places it on the pistil of the other white-flowering plant. ▲ Then, as in the picture, he puts a bag over the flower. Why? Bees and other insects collect pollen. The insects can carry the pollen to other flowers. That is, insects can **cross-pollinate** (krô's' pol'ə-nāt) flowers (carry pollen from flower to flower). In this way, it would be possible to produce red-flowering plants. Placing the bag over the flower prevents unwanted cross-pollination.

In this way the plant grower can produce seeds which he is sure of. Whenever he plants seeds labeled "white-flowering peas," he is sure to get white-flowering plants. The seeds for white-flowering garden peas will have genes for producing only white flowers. To keep the plants *pure*, the plant breeder must make sure that red-flowering plants pollinate red-flowering plants and that white ones are crossed only with white ones. Perhaps you would like to try your luck at cross-pollinating flowers. In the investigation on the following pages you will find out how. Try it yourself.



AN INVESTIGATION into Cross-Pollination of Petunias



Needed: tweezers; scissors; plastic bags; red and white petunias; a small brush

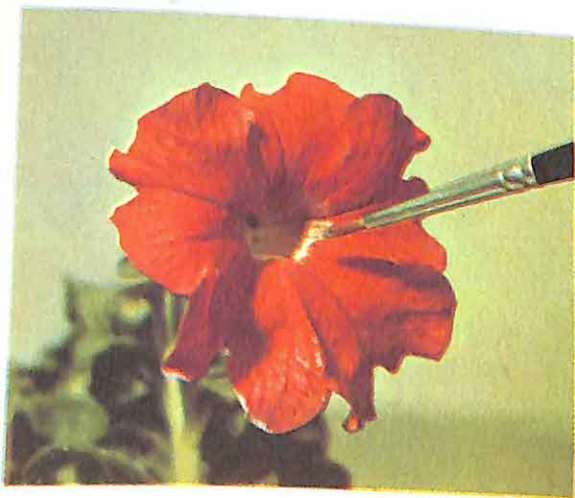
Set up your own investigation into cross-pollination. Here is the way one girl tried her luck at crossing red and white petunias.

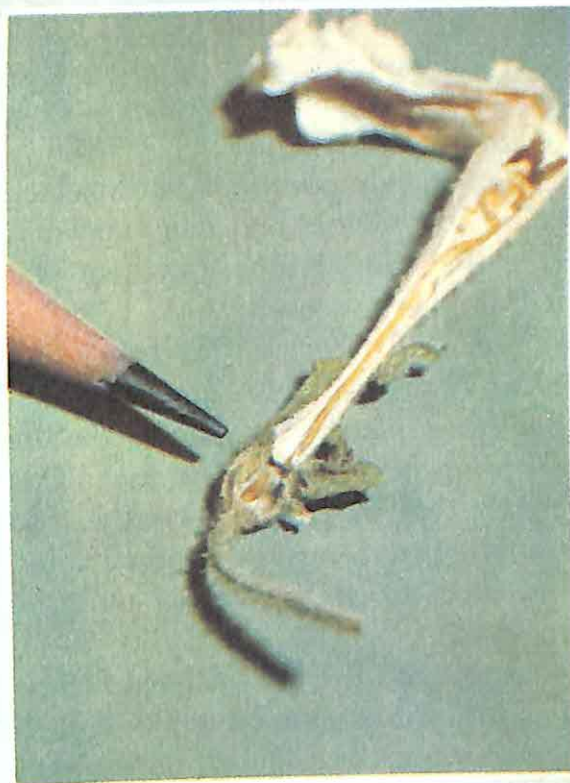
With a tweezer, she opened the bud of a white petunia plant, and with a pair of small scissors, she cut off all of the stamens to prevent the flower from pollinating itself. ■ Then she covered the bud with a plastic bag and waited for it to reach full bloom. ●

When the white flower was in full bloom, she removed some pollen from the stamen of a red petunia with a small brush, as shown. ▲

She then removed the plastic bag and brushed the pollen onto the pistil of the white flower. ◆ She immediately replaced the bag in order to prevent other pollen from getting onto the pistil.

When the flowers dried out, she removed the seed cases which contained several very tiny seeds from the base of the pistil and saved them all in a dry place until the next spring. ★ Then she planted the seeds and cared for them until they grew into new plants. Which plant (in the picture) did the offspring of the red and the white petunia plant look like? ◆ What is your prediction? Do you need further study?





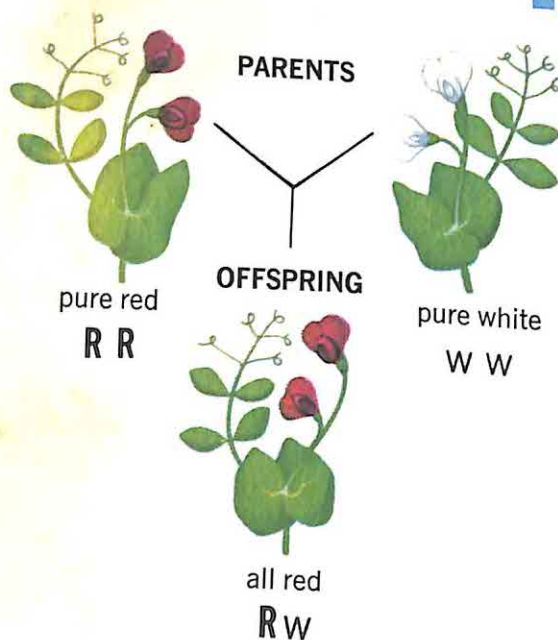
Red Crossed with White

What happens when a red-flowering garden pea plant is crossed with a white-flowering plant?

First, it is important to know which color is *dominant* and which color is *recessive*. Here is one statement that will give you a clue.

When a pure red-flowering pea plant is crossed with a pure white-flowering plant, the flowers on the offspring will always be red. This means that in garden peas the trait for red flowers must be dominant, and the trait for white flowers must be recessive.

Let us call the gene for red flowering R and the gene for white flowering w . A pure red-flowering plant has genes for red flowers only (RR). One gene (R) was inherited from each parent cell. A pure white plant has genes for white flowers only (ww).



The capital letters (RR) show that the genes for red flowering are dominant. The small letters (ww) mean that the genes for white flowering are recessive.

What would the genes be in a plant which was a result of crossing a pure red (RR) with a pure white (ww)?

The pure red (RR) plant would pass on a gene for red (R). The pure white (ww) plant would pass on a gene for white (w). What color would the flowers of the offspring be? *Study the diagram carefully.* ■ Ask yourself this question: When a pure red *dominant* is crossed with a pure white *recessive*, what color will the offspring be?

A Plant Made to Order

For many kinds of plants, plant growers know how to get the genes they want into a new plant. First, they try to produce a plant pure for the genes they want. Then they must cross the pure plants with each other. Pure red-flowering pea plants crossed with pure red-flowering pea plants will give a pure red-flowering plant.

What you have learned about pea plants is true also of other plants and animals which are bred for a certain trait. The main thing to do is to produce a plant or animal which is pure for the genes that are wanted. Then a cross with another plant or animal that has only the genes that are wanted is needed. In this way, it is possible to be fairly certain of the heredity of the offspring.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. To be sure that he will get the kinds of genes he wants, a plant breeder controls

- a. pollination
- b. growth

2. In garden pea plants, red flowering is dominant over white. When a pure red plant is crossed with a pure white plant, the offspring will be

- a. white
- b. red

3. A pure purple-flowering plant is crossed with a pure yellow-flowering plant. All the seeds produce purple flowers, so the purple flowering must be

- a. dominant
- b. recessive

4. A pure black-furred guinea pig is crossed with a pure gray-furred guinea pig. Gray fur is recessive. All the offspring will be

- a. gray-furred
- b. black-furred

B. Write a paragraph or two on this topic: Dominance and Recessiveness.

**USING WHAT
YOU KNOW**

1. A rancher breeds cattle.

a. Why would he need to know what genes the cattle will inherit?

b. Suppose he was interested in the way his cattle put on weight. He knows that they have genes for fast growth. Why would he need to be sure that the animals have a good environment as well?

2. Scientists have found that by careful mating, or crossing, of animals or plants, many desirable traits can be carried on to the offspring.

Why do dog breeders who want pure-bred dogs, such as spaniels, or scotties, mate only pure-bred animals with each other?



dominant



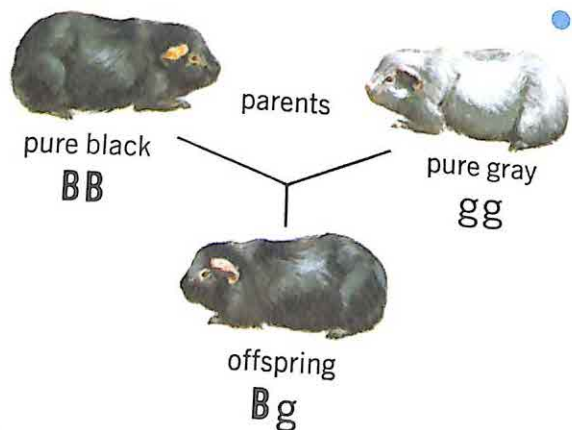
recessive

4. Blending Traits

Scientists learn more and more as they investigate.

After Mendel had written about his experiments in 1859, it was thought that genes were either dominant or recessive. Tallness in garden peas is dominant over shortness. Red flowering in garden pea plants is dominant over white flowering. ■

Black fur in guinea pigs is dominant over gray fur. When pure black-furred guinea pigs are crossed with pure gray ones, all the offspring are black-furred. ● In chickens the genes for red



feathers are dominant over the genes for white feathers. What color are the offspring of pure red-feathered roosters and pure white-feathered hens? They are red-feathered, of course.

All of this seemed very clear until a German scientist, Carl Correns, began studying another common garden flower. He was interested in how traits in "four-o'clocks" were inherited.

Correns started growing and crossing pure red and pure white four-o'clocks. He did not get the results he had expected.

A New Concept

When pure red pea plants are crossed with white, all the offspring are red. When Correns crossed pure red four-o'clocks with pure white plants, the offspring were neither red nor white. *The offspring were pink.*

What is the explanation for Correns' results? Obviously, there must be genes which are neither dominant nor recessive. Perhaps the genes act together to produce a **blend** of a certain trait. Perhaps, in four-o'clocks, the gene for red acts with the gene for white to produce pink flowers. Correns discovered a blend of flower colors. The results are the same as when an artist mixes red paint with white paint to get pink.

Let us review the facts.

A pure red pea plant is crossed with a white pea plant to give all red pea plants. Red color is a dominant trait in pea plants so the offspring are red.

The white plant is recessive. Therefore, it is pure. Do you see why? White plants must have genes only for white (ww). If they had one gene for red (R), they would be red because red is dominant.

A pure tall pea plant crossed with a pure short pea plant gives all tall pea plants. Tallness is a dominant trait in pea plants.

But: A pure red four-o'clock crossed with a pure white four-o'clock produces all pink four-o'clocks.

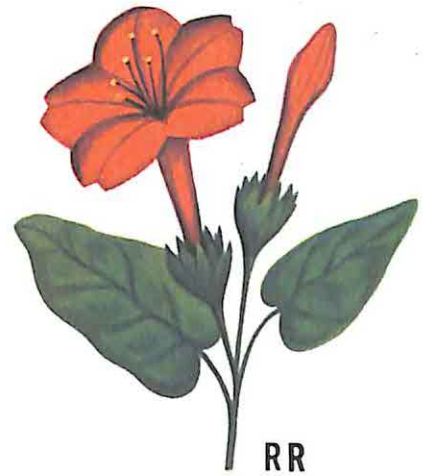
Neither red nor white is dominant. Scientists call this blending.

The Pink Four-O'Clock

Suppose you could look inside the cells of a pink four-o'clock, the flower that came from the crossing of a red four-o'clock with a white one. What genes would you find in each pink four-o'clock?

You know what the color genes are in a red four-o'clock. These could be written as RR. How will we write those in a white four-o'clock? Write them as WW since they are *neither* dominant *nor* recessive to the red.

A pure red four-o'clock crossed with a pure white four-o'clock results in a pink plant which has the genes RW. One gene (R) must have come from the red plant. One gene (W) must have come from the white plant. The new plant must be RW—*pink*. ▲ Notice that capital letters are used for both red and white genes. Small letters are used only to represent genes that are recessive.



A Code from Parents

All living things get their DNA code (their genes) from their parents. Geneticists (jə-net'ə-sists), scientists who study heredity, have found this to be true again and again. They have called a living thing with two similar genes for a certain trait (red color, for instance) pure for the trait. When a four-o'clock plant has genes for red color (RR) only, it is pure for this trait.

On the other hand, the offspring, the pink plant, has different genes (RW) for the same trait—color. Geneticists call a living thing with different genes for the same trait a hybrid (hī'brid). ■

A pure tall plant (TT) crossed with a pure short (ss) will produce hybrid tall plants (Ts). The hybrid has genes for tallness and genes for shortness. Pure red pea plants (RR) crossed with pure white pea plants (ww) will

produce hybrid red plants (Rw). In these hybrids, the gene for red is dominant. The dominant gene seems to cover (or hide) the recessive one.

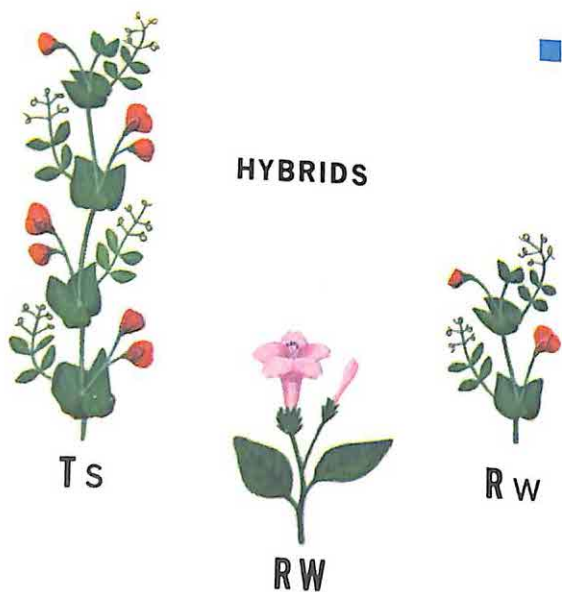
A pure red four-o'clock (RR) crossed with a pure white four-o'clock (WW) will produce hybrid pink plants. Neither gene is dominant. The genes seem to blend the colors. It seems then that there are two kinds of hybrids. In one kind, one gene seems completely dominant (Rw) and hides the other, the recessive (w). In the other kind, the genes are incompletely dominant (RW).

Other Hybrids

You may know of some hybrid animals. Texas cattle have long been famous for their beef. Unfortunately, they are highly susceptible to Texas fever, which kills many of them. Brahman cattle are cattle that were developed in India. They are immune to Texas fever.

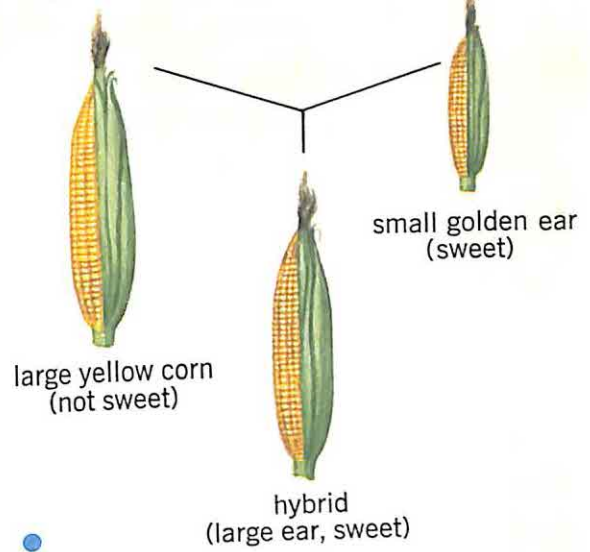
When a Brahman bull is crossed with a Texas cow, hybrid cattle are produced. The offspring do not get Texas fever. The hybrid is an improved animal that is immune to disease. These animals stay healthier than many other kinds of cattle. Because of this, they are said to have prize genes, and they are very much in demand.

The ears of corn shown in the picture are ears of hybrid corn. ● They are much larger ears than those of one of the parent plants and much sweeter tasting.



What about a mule? A mule, too, is a hybrid. It is the result of crossing a female horse with a male donkey. A mule is stronger than either parent.

Hybrids, such as the offspring of the Brahman bull and the Texas cow, the mule, or hybrid corn, may be prize packages of genes. Geneticists, in breeding plants and animals, try to get the best of all genes into the offspring. Thus, plants and animals can be improved and made more useful.



BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you to fix in mind the concepts of this section.

1. The trait for red feathers is dominant over white. When pure red-feathered roosters are mated with white-feathered hens, the result is
 - a. only red-feathered chickens
 - b. only white-feathered chickens
 - c. rust-feathered chickens
2. When pure red four-o'clocks are crossed with pure white four-o'clocks, all the offspring are
 - a. pink
 - b. white
 - c. red
3. When white four-o'clocks are crossed with white four-o'clocks, the offspring are
 - a. red
 - b. white
 - c. pink
4. Pink four-o'clocks are
 - a. hybrids
 - b. pure
5. When pure tall pea plants are crossed with pure short pea plants, all the offspring are
 - a. hybrids
 - b. pure

B. Write a paragraph or two on this topic: Heredity and Environment.

USING WHAT YOU KNOW

1. Hybrid animals and hybrid plants are important to us. Name at least one hybrid animal and one hybrid plant. In what way are they important to us?
2. Why are some hybrids often thought of as prize packages of genes?

ON YOUR OWN

Mendel and Correns were scientists who studied the effects of the genes. The findings of such scientists were applied by technologists to make new and improved species of plants and animals.

To find out more about the work of a great plant technologist, look up the life of Luther Burbank in the library. You will be interested in reading about some of his amazing accomplishments—a good example of how science and technology go hand in hand in improving plants and animals.

5. Changing the Code

Perhaps you had a fresh orange today. Did it have lots of seeds or was it a seedless orange?

Did you ever ask yourself how a seedless orange came to be? Since it has no seeds, one cannot plant seeds in order to produce more seedless oranges.

How did the first seedless tree come to be? The first one must have come from a tree that produced seeds. It did. Seedless oranges come from oranges with seeds.

The seeded orange must have had genes for producing seeds. Wherever a seed is planted, the tree produces fruit with seeds. One day, however, a tree was found that had good oranges, without seeds. The seedless orange tree must have grown out of a seed from a seeded tree.

One explanation of why this happened makes sense. There must have been some kind of change in the genes. The genetic code must have changed from a code that produced the trait *seeded* to one that produced the trait *seedlessness*.

Scientists now know that genes can change. Genes that change are called **mutant** (myōō'tənt) **genes**. Seedlessness in oranges and in grapes was caused by genes that were mutant. In other words, the genes for seeded *mutated* to produce genes for seedlessness. Genes for seedlessness are prize genes. It is much more pleasant to eat a seedless orange.

The picture shows a longhorned Texas steer. ■ The picture is an old one, because the longhorned animals are rapidly dying out. One day a shorthorned animal, a **mutant**, was born. The gene for the characteristic *long horns* had mutated into a gene for *short horns*.

Ranchers find shorthorned cattle easier to handle and easier to ship because they do not hurt each other when loaded into close quarters.

When animal or plant growers decide that a mutant is useful or more desirable, they try to produce more plants or animals with the same mutant genes—if they can.

Most orange growers would like to have many seedless orange trees. A seedless orange is much nicer to eat than an orange with seeds. People are usually willing to pay a higher price for seedless oranges.

Many years ago the first seedless tree was brought here from Brazil. Each year seedless oranges are becoming more and more plentiful, because plant scientists have developed a method for producing new seedless orange trees.



Suppose you wanted to develop such a method; how can it be done with a seedless orange? You have no seeds to plant.

Propagating a Mutant Plant

Imagine that you are an orange grower and that you find a tree with seedless oranges. How would you produce more seedless orange trees?

You may have taken a twig of a willow and tried to root it in moist sand. This method would work well with begonias, geraniums, and with many other plants. Yet it is not the best method for growing seedless orange trees. The best way of doing this is to make a twig grow on the roots of another tree. For the orange, a twig of the seedless plant is often grown,



branch from seedless orange tree



root
of
lemon
tree



plant growers say **grafted**, on the root of a lemon tree. ■ This root is called the root stock. Notice in the top picture a small branch has been cut from a seedless orange tree. The cut was made in the shape of the letter V.

A young lemon tree is cut off at the root in the same manner. The second picture shows how the lemon tree was cut quite close to the ground, leaving only the roots and part of the trunk. The cut on the trunk is like an upside-down V. This prevents rain from getting in later, when the tree is grafted. The branch of the seedless orange tree is then grafted onto the root stock in its place. The graft is sealed, and cloth is wrapped around it to give it

support. This will now grow into a full-sized seedless orange tree. Each branch taken from the seedless tree can also be grafted to a separate root. Each will grow into another seedless tree. Then, later on, branches can be taken from each of these to produce even more seedless trees.

By means of grafting, many seedless trees can be derived from one. Grafting is used to save the traits of a useful mutant and to get many offspring from the original plant. Perhaps you would like to try your hand at grafting by doing the investigation on the opposite page.

Saving a Mutant Animal

Saving the prize genes of an animal mutant is not so simple. Consider the mutant shorthorned cattle as an example.

Genes for shorthorned cattle are prize genes because they produce a desirable trait which the ranchers want. Suppose one offspring from longhorned cattle has short horns. The cattle rancher must wait until it grows up before it can produce offspring. Till then, he feeds it and takes good care of it. At last he crosses the mutant shorthorn with a longhorn. He wonders if the offspring will be a longhorn or a shorthorn. He can only wonder and wait.

Luckily, in this case, the prize genes for short horns are dominant over the genes for long horns. The offspring is another shorthorn. Since one parent was a shorthorn and the other was a

AN INVESTIGATION into Grafting

Needed: a branch to be grafted; a stock root; grafting wax; string or strips of cloth

One method that can be used is to graft a branch onto a stock tree in the early spring when the sap begins to rise in the trees. The branch and the stock tree must be closely related types, such as two kinds of apple, apple and pear, or orange and lemon.

Remove a branch from the mutant tree by cutting diagonally, as shown. ■

Select a branch about the same size as the branch stock to which it is to be grafted. Cut the branch diagonally.

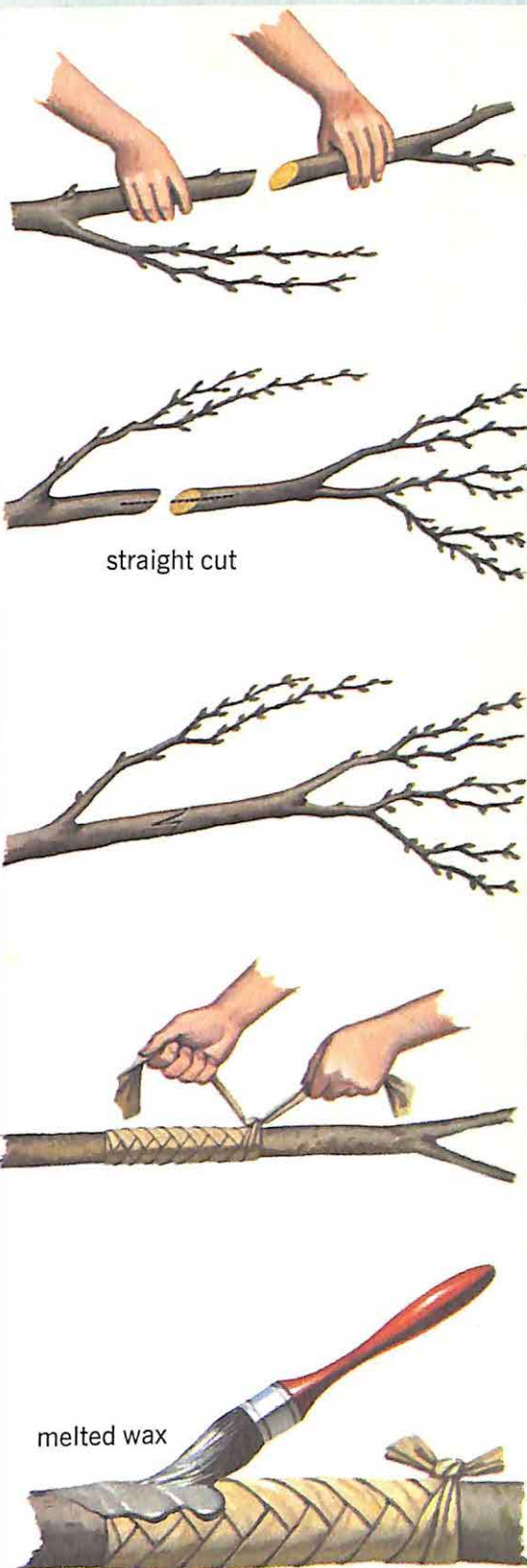
Make a straight cut in the two parts that are to fit together, as shown. ●

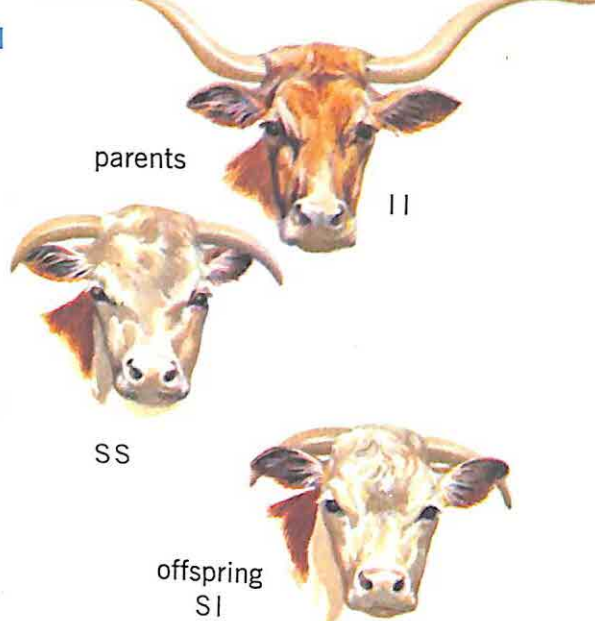
Insert the branch so that the letter "N" is formed. ▲ Then wind a string or cloth around the joint several times and tie it tightly. ◆

After the branch is tied, cover the graft with grafting wax or melted paraffin to keep it from drying out. ★

The new branch should become tightly fastened to the tree during the first summer. It should grow leaves and, possibly, fruit. What kind of fruit will it have? Suppose a pear branch is grafted to an apple tree. What will grow on the branch, apples or pears?

On what evidence do you base your answer? What theory explains why grafting is possible?





longhorn, the offspring is a hybrid having genes for both long and short. ■ But the cattle rancher wants only shorthorned cattle. To do this, shorthorned cattle are crossed many times with other shorthorns. At last a herd of pure shorthorns is developed.



A package of prize genes, then, can be saved in at least two ways. For plants, grafting is used wherever necessary and possible. For animals, the mutants are crossed to produce hybrids until a sufficient number of mutants are born.

Causing Genes to Mutate

Scientists had been looking for a way to change the genetic code in chromosomes. Dr. Hermann Muller found a way. He changed the genes in an insect, the fruit fly. ● Genes in which the code has been changed and inherited by the next generation are called **mutations** (myōō-tā'shənz).

Fruit flies are easy to find indoors and outdoors. They are small enough to pass through most screens.

Collect some fruit flies in the late spring or summer. (The winter season is usually not a good time.) The insects will not hatch until the days are warm. Examine some fruit flies, as in the investigation on the opposite page.

Mutations in Fruit Flies

The fruit flies used by Dr. Muller were very much like the ones you can collect. They were, however, pure for certain traits.

For instance, some had white eyes and others had red eyes (as shown in the picture). Some had short wings and others had long wings.

White-eyed fruit flies produce white-eyed offspring. What kind of offspring would pure long-winged flies produce?

AN INVESTIGATION into the Kinds of Fruit Flies You Can Find

Needed: some raw fruit (bananas or grapes) or some stewed fruit; a jar; some cotton, cloth, and paper; a magnifying glass

Put some raw or cooked fruit into an open jar. If you do this during the warm season, you may soon find tiny flies swarming around the fruit. Place some soft paper above the fruit to help keep the flies in the jar until you cover it.

Once the fruit flies have begun to collect on the fruit, close the jar with a wad of cotton or cloth. ■ This will allow air to get to the flies. Examine them with a magnifying glass. ● Are they all alike? Look at the eye color and the shape of the wings, for example. Perhaps if you keep them long enough, they will lay eggs. Then you may have a swarm of tiny fruit flies. Are they like those shown in the picture? ▲





long-winged



short-winged



curly-winged

Remember that Dr. Muller used flies which were pure for a certain trait, for example, for long wings. ■ He bombarded the flies with X rays. Then he examined the offspring. Among the offspring, he found mutants. Flies with genes for *long wings* *only* had produced offspring with short or even curled wings. The genetic code appeared to have been changed by X rays. Mutants resulted. Dr. Muller proved that X rays could cause mutations, or changes, in the genes. For his discovery, Dr. Muller received a Nobel prize. Since then mutations have been brought about in many experimental animals and plants by the use of X rays and other types of radiations.

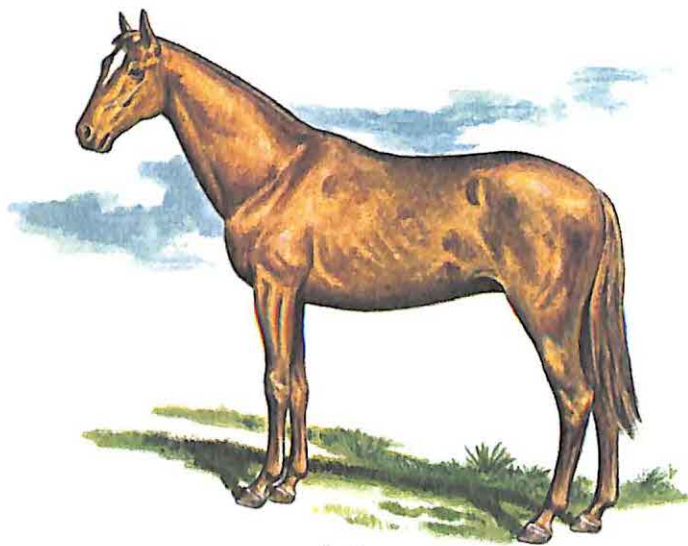
Change Over the Ages

Scientists of today can cause genes to change, or mutate. Can genes change by themselves? Is there a natural change, or mutation, going on in the genes of living things? There is strong evidence that animals and plants have not always been as they appear now. It is believed that the modern horse, for example, came from an animal that was no larger than a fox. ● Slowly, over millions of years the foxlike horse (the "Dawn Horse") changed. Other animals have also changed over millions of years.

Early horses had more than one toe on each foot but the modern horse has only one. How could this change have occurred? The explanation is that the



60 million years ago



today

genetic code for toes changed, that is, the genes mutated. The genes for size of body and skull also mutated. Over millions of years, many mutations resulted in the modern horse. ▲

Ages ago, huge dinosaurs roamed the land. You may have seen pictures of the many kinds. How could so many different kinds of dinosaurs come to be? A good explanation is that they were the result of mutations taking place over millions and millions of years. Then they died out over 60 million years ago.

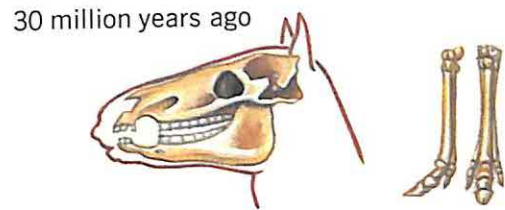
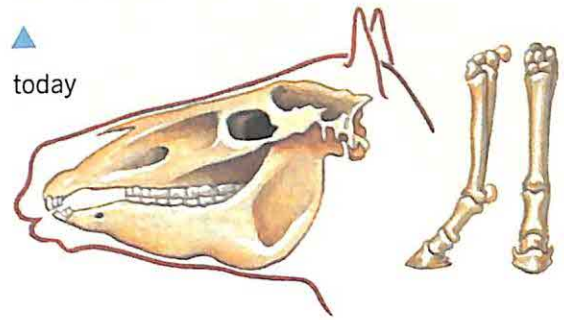
Scientists believe that many new forms of animals and plants have resulted from mutations in genes. In other words, the changes which have occurred in living things, over millions of years of time, are the result of changes in genes.

Not all mutants survive. In fact, most mutants die out. Why is this so?

Suited to the Environment

Each kind of animal and plant which exists on earth has lived for a long time in its surroundings. For instance, a fish lives in water. It uses its gills to get the oxygen which is dissolved in water. Suppose the genes which produce the gills mutated, and a fish without gills is born. It will die because it cannot get oxygen. An animal or plant is adapted to live in a certain environment or it will die.

Sometimes a certain environment changes, and the living things are not able to survive in the new environment. One theory that may explain



why the giant reptiles, the dinosaurs, died out is the following. The dinosaurs lived in an environment that was fairly moist. Slowly, over millions of years, the land began to dry out and change in many other ways. The plants changed. The food supply changed. In any event, the dinosaurs died out. It seems as if the changes in the dinosaurs did not keep pace with the changes in environment. Perhaps the genes did mutate but not in a way for dinosaurs to survive.

Some mutations help the animal or plant to live better in the environment, but some do not. Sometimes mutations make it possible for the organism to survive in a changing environment. Perhaps this can explain the changes that have occurred in the horse.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Shorthorned cattle probably arose as
 - a. mutants
 - b. hybrids
2. A seedless mutant tree can be saved by
 - a. grafting
 - b. planting
3. With animals, mutants can be crossed with purebred animals (nonmutants) to produce
 - a. pure animals for a trait desired
 - b. hybrid animals for a trait desired
4. Mutants in fruit flies were produced by Dr. Hermann Muller by using
 - a. X rays
 - b. grafting
5. The evidence shows that animals and plants have changed over millions of years. The changes in genes were due to
 - a. mutation
 - b. hybridization
6. When certain kinds of living things like the dinosaurs die out, we say they were
 - a. not fitted to the changing environment
 - b. a prize package of genes

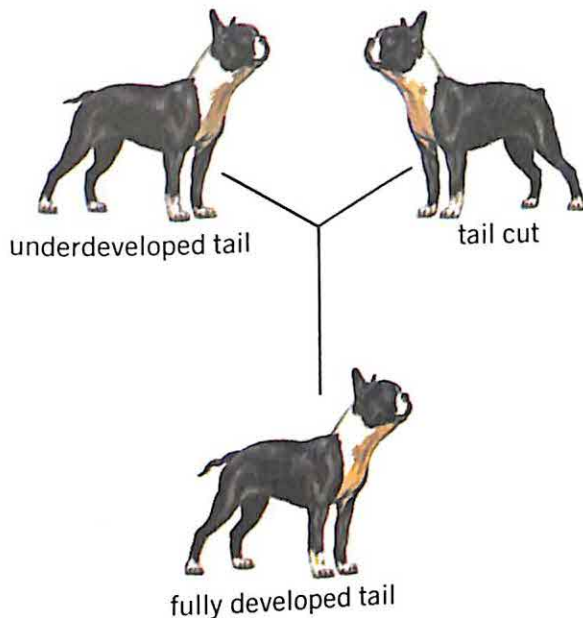
B. Write a paragraph or two on this topic: Mutations.

**USING WHAT
YOU KNOW**

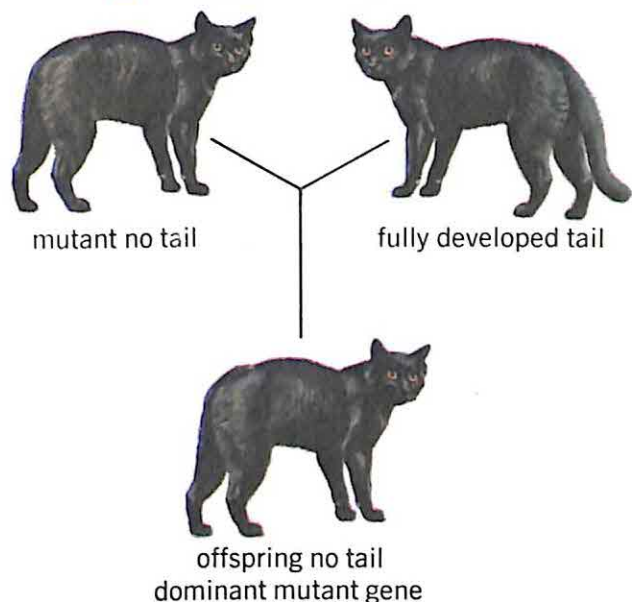


1. Below are pictures of the eyes of fruit flies. ■ The red color is the color most commonly found. What is your explanation of how the other colors of eyes developed?
2. Over 60,000,000 years or so, the feet of horses have changed from those of the three-toed horse to those of the one-toed horse. (The hoof is really the nail of the huge middle toe.) What is your explanation of why the toes of the horse changed over millions of years?

● ENVIRONMENTAL CHANGE



▲ MUTATION OF GENES



6. The Search for Prize Genes

Suppose you are a rancher who wants to improve his herd of Herefords (*hūr'fərdz*). These are the familiar white-faced cattle which are bred for beef.

Suppose, too, that on your ranch, a new bull calf is born. As he grows, you find that he is different from every other bull in your herd. He is white-faced, and he has a red coat like the other Herefords; but he is hornless or **polled** (*pōld*), as cattle raisers call it. He is not just shorthorned. He is truly hornless. What a prize! Horns of any kind are troublesome when cattle are being shipped.

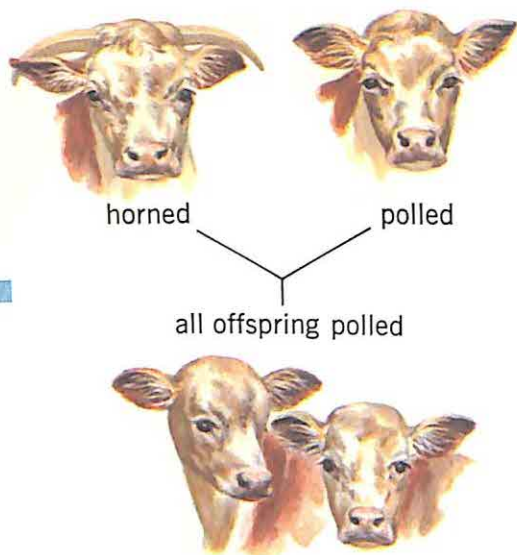
You might suspect that he is a mutant and that the genes for *horned* have changed to genes for *hornless*. Does he really have prize genes within him or is his lack of horns the result of

his environment? Perhaps he just has not developed like other bulls.

When animals do not develop as they should, they may not have their horns or they may be born without tails (as shown in the picture); but they may still have the genes for the trait which did not develop.

The offspring of the toy bulldogs has a normal tail because his parents' tails were stumped by environmental causes. ● No change in the genes took place. One of the Manx cats, on the other hand had a mutant gene for "no tail," which was inherited by the offspring. ▲

There is only one possible way to make certain that a gene has mutated and that is to look at the offspring of the animal we think is a mutant. If the gene has really changed, then the mutant trait may show up in succeeding generations.



A Prize Gene—Hornlessness

Not long ago, a rancher in Iowa found that a prize mutant had been born on his ranch, a polled Hereford bull. He wanted to build an entire herd of polled Hereford cattle. How could he do it? He had only one polled Hereford bull, and he desired to raise an entire herd of polled cattle. He decided that he needed help. He sent out letters to 25,000 ranchers who had been raising Herefords, asking if they had any polled cattle that he could use for breeding. In this way he found four more mutant polled bulls and ten mutant polled cows.

He crossed polled bulls and polled cows. The offspring were all polled. When these offspring grew up, he again crossed them, and again he got polled offspring. Was the gene for polled dominant or recessive? How would you find out? The cattle raiser, or cattle breeder, found out in the following way.

He crossed *polled* cattle with *horned* cattle. All were Herefords. The only difference in them was that some were polled and some were horned.

If the genes for polled (hornless) cattle were dominant over the genes for horned, what would the offspring be? On the other hand, if horned were dominant over polled what would the offspring be? All the offspring developed as shown in the picture—polled. ■ In this way, one rancher developed a herd of polled Herefords.

Today the polled Hereford is one of the most popular kinds of cattle. They range in Canada, South America, Australia, and in other countries. In the United States alone there are over 50,000 registered Herefords. "Registered" means that their breeding (their inheritance with regard to certain genes) is known.

In other words, the genes of registered animals are known. They are prize packages of genes not only for hornlessness but also for good beef production. Today, however, the Herefords are being challenged for beef production by another breed of American cattle. It all began with a bull named Monkey.

The Story of Monkey

Cattle ranchers have always been searching for ways of improving their cattle—to produce a larger quantity and better quality of beef.

Ever since 1910, ranchers had been crossing American Brahman bulls

(shown in the picture) with Texas shorthorned cows. They were trying to produce cattle which not only had better beef but which also were resistant to certain diseases. They also wanted cattle which could stand a hot and dry climate.

In 1920, Monkey was born on the famous King Ranch near Kingsville, Texas. Monkey had prize genes. Monkey was one of the ancestors of the prize bull you see in the picture. ● This bull is one of the Santa Gertrudis (san'tə gər-trud'is) bulls.

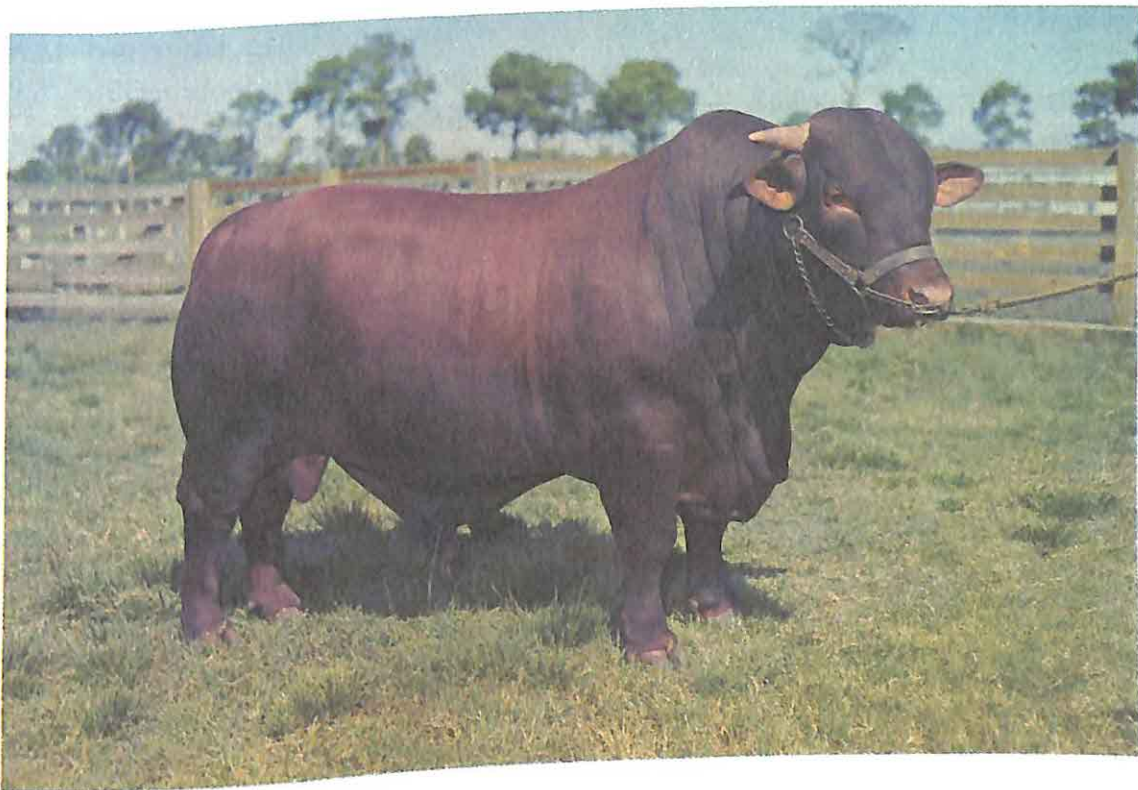
The Santa Gertrudis cattle are fast becoming the most important beef-producing cattle in the country. Look at the Santa Gertrudis bull; he is strong and able to endure a dry, hot climate. He is a prize package of genes.

Prize Genes in Plants

Mutants also occur in plants. The Katahdin potato is the result of crossing many different strains, or kinds, of potatoes. Some strains of potatoes that were crossed had genes that had mutated so that the Katahdin inherited a resistance to some diseases (such as potato blight). Potato blight once wiped out almost the entire crop of potatoes in Ireland.

"Wilt" in tomatoes is a disease which causes the leaves to wilt and the plant to fall over. The leaves of the tomato plant turn brown and can no longer make food. The plant dies before it can produce any tomatoes.

There is a similar disease which causes the cotton plant to wilt. Plant geneticists searched for tomato and





cotton plants which were resistant to wilt disease. They found them. Now there are strains of tomatoes and cotton which are very successful in resisting this disease. Notice that next to a healthy plant, the plant with wilt looks dried out. ■

Resistance to disease often can be traced to genes. For instance, the strain of wheat known as *Rival* wheat has genes for resistance to rust disease. Scientists produced the *Rival* strain after crossing American and Canadian strains. There are now strains of wheat, corn, and oats that have genes for resistance to rust bred into them.

Desirable plants and animals are prize packages of genes. Next time you go to a food market, take a look at the fruit and vegetable department. You may see boxes of giant red strawberries or blueberries as big as marbles. Look at the bin of large mild Bermuda onions and the firm cabbages. Almost all the fruits and vegetables you see have resulted from cross-breeding of plants with prize genes.

USING WHAT YOU KNOW

1. Find as much information as you can on a particular kind of plant or animal. You may wish to choose a kind of animal (Hereford cattle, white leghorn chickens, quarter horses) or plant (potatoes, apples). Perhaps there are new forms of these animals or plants being produced.

How can you find out which kind you are interested in? There are many ways; here are some.

- a. If you live on a farm, your parents may suggest an animal or plant. Or perhaps you can talk to the county agent.
- b. If you live in the city, try the reference books in the library.

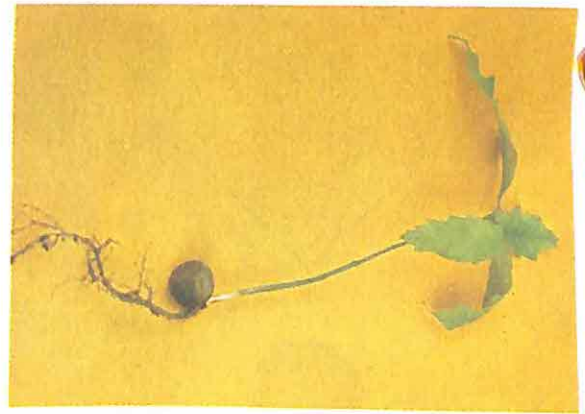
2. Write a report on the plant or animal you have selected. Be sure to organize your report to include: a. the origin of the plant or animal; b. how it was bred; c. the kind of environment it needs; d. its uses to man.

7. The Main Concept: The Genetic Code

The seed of an oak tree, the acorn, is planted. When conditions are right, the roots and the stem begin to develop. ● Whether it grows to its full height or is stunted depends on the kind of soil and the minerals in it. It also depends on whether the plant has enough water and sunlight.

Whether the tree is to be a maple or an oak depends on the chromosomes in the nucleus of its cells. More than that, the chromosomes pass on special traits: the shape of the leaves, the color of the bark, or the shape of its seeds and fruits.

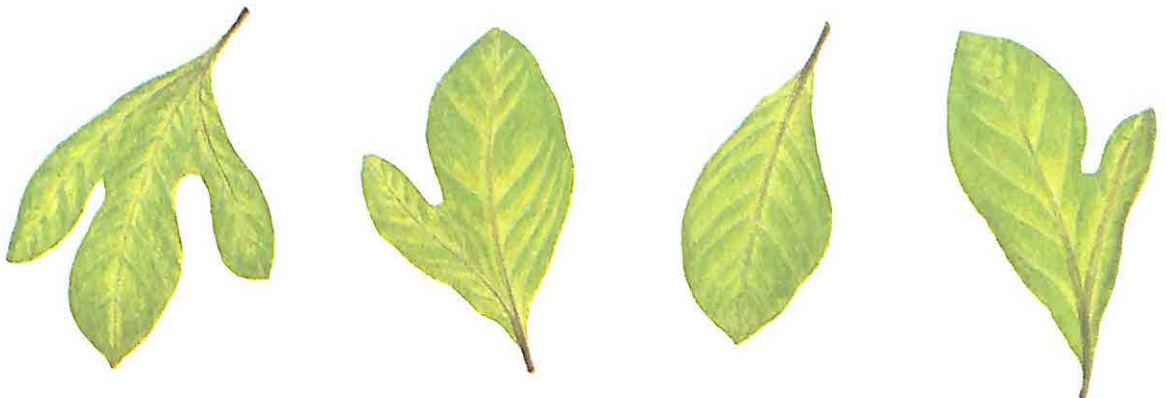
The DNA molecule in the chromosomes of the nucleus carries the code, the “message,” which determines what traits the organism will have. The environment plays a great part in determining how these traits will develop in the organism. Leaves from any tree may have about the same shape as those from a sassafras tree, shown in the picture. ▲ They may be large or small, deep green or light

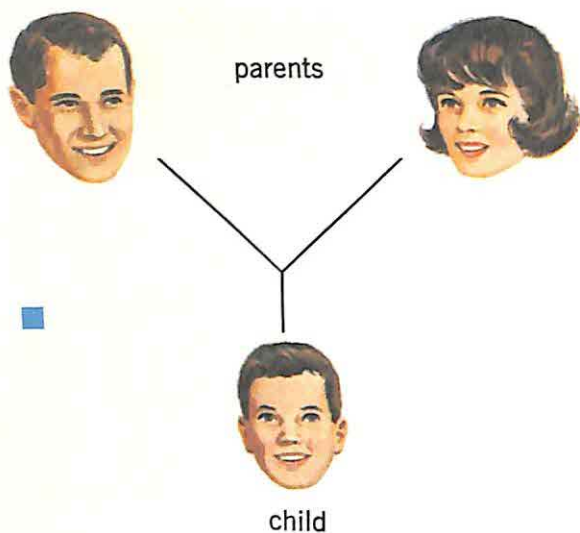


green. There may be many leaves or few, depending on the soil, water, and sunlight the tree gets. An *organism is the product of its heredity and the environment in which it develops*. Both are important to its growth and appearance. This is a major concept.

The concept just stated is true of oaks, maples, roses, horses, dogs, cats, lions, frogs, kangaroos, and raspberries. It is true of all of us. There is one great difference, however. We can understand that we are the product of our heredity and our environment. We can try, therefore, to provide the best environment. The good traits we have inherited from our parents will then develop to their fullest. It is not

▲ SASSAFRAS LEAVES





much use to inherit genes for a trait, such as height, without also being sure that we eat the right food, so that we can develop as well as possible; nor is it much use to inherit high intelligence without making sure that we use our intelligence through study and learning.

The story is not as simple as it sounds, however. Even the codes in the chromosomes produce different results depending on the combinations of genes which are inherited. A four-o'clock has red flowers only when it is pure for red flowering. It has white flowers only when it is pure for white flowering. It is pink, however, when it is a hybrid—that is, when its inherited code is for both red flowering and white flowering.

Scientists are just beginning to learn of the inheritance of human traits. Physical traits such as eye color, hair color, shape of body, height, features, and skin color are all coded in our chromosomes. The way some of

these traits develop is affected by the environment. Eye color does not change because of environment, but the size of the body depends on what we eat, as well as on heredity. The way we do things depends not only on our intelligence (which is inherited) but also on our education. Thus, what we learn, how we learn, or the way we learn is a result of both our inherited intelligence and our environment working together.

The investigations that scientists have made of the DNA molecule within the chromosomes and their study of the way chromosomes are transmitted from parent to offspring have made it possible for scientists to improve plants and animals. The work of a geneticist takes a long time but can be very successful. Now there are hens which lay an egg a day; there are ears of corn that are twice the size and much sweeter to the taste than those produced by corn plants a few years ago.

A farmer of 100 years ago would be surprised if he were to visit a market today. The changes in the fruits, vegetables and meats sold there are great. The work of the plant grower and of the animal breeder has resulted in more and better food for all of us.

Geneticists began studying heredity only at the beginning of this century. They see, in the code of the genes in the DNA molecule, the clues to questions such as these:

1. *Why is it that the offspring are like the parents?*

Clearly, offspring get their traits from their parents. A dominant gene which both parents have, such as the trait for black hair, is likely to show up in the children. This is shown in the diagram. ■ Do you know any children who seem to be very much like their parents?

2. *Why is it also possible that the offspring can be somewhat different from their parents?*

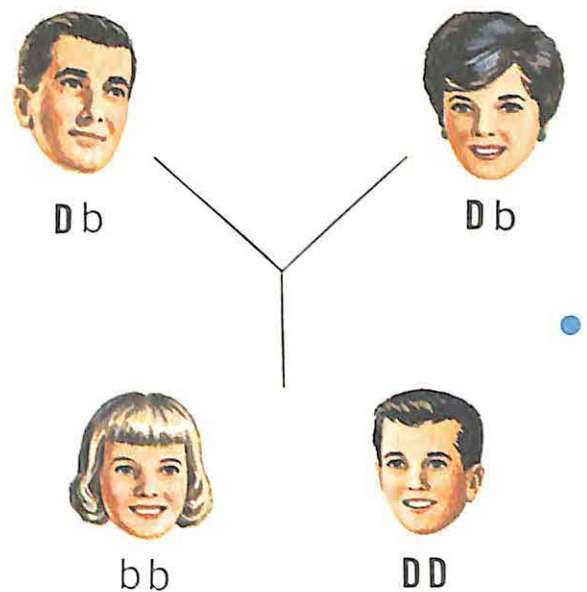
Suppose that both black-haired parents have inherited the recessive genes for blond hair as well (as in the diagram). ● Then it is possible for their child to have blond hair.

Thus it is possible for a child to show traits different from those of either parent. Do you know any children who have differences from, as well as similarities to, their parents?

3. *How is it possible that living things have changed over the millions of years of the earth's existence?*

We know animals and plants have changed over millions of years. The horse, as you have seen, has changed in many ways. Dogs and cats are very different from their ancestors of long ago. Dinosaurs no longer exist on earth. No one is exactly sure how or why these changes took place.

The scientist's explanation is that the genes must have mutated. Those living things whose mutant genes helped them *adapt better* to their environment survived. Those organisms whose mutant genes did not fit them to their changing environment died out.



Over millions upon millions of years organisms have changed. This is one of the major concepts of science. Everything has changed. The earth has changed. Organisms have changed. Some species of plants and animals have died out. Some have become much stronger and heartier, while others, such as the turtle, seem to have changed more slowly.

The life of the past gave rise to the life of the present. Living things have changed during the millions upon millions of years the earth has been spinning around the sun.

What about the future? Will changes in the universe continue to take place as they have in the past? What is your hypothesis of how living things will have changed 100,000,000 years from now? Base it upon your knowledge of how they have changed in the past 100,000,000 years. Even if you can develop a sensible hypothesis, are you likely to witness the proof?

Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts in this unit by doing these problems.

1. Recall that a theory is a reasonable explanation of the facts. Which of these theories on the way we inherit our traits would you accept?

- a. Living things inherit their traits through the blood.
- b. Living things inherit traits through chromosomes.

Give reasons for your answer.

2. Which of these theories would you accept?

- a. Living things have remained the same over the entire time of the earth's existence.
- b. Living things have changed over the time of the earth's existence.

Give reasons for your answer.

3. A yellow-flowering plant is crossed with another yellow-flowering plant. Only yellow-flowering offspring are produced.

What is your explanation of the results?

4. A black-furred guinea pig is crossed with another black-furred guinea pig. The offspring are both black-furred and gray-furred.

What is your explanation of the results?

5. The gene for blue eye color is recessive to the gene for brown eye color. Two parents, both with dark brown eyes, have four children: three are brown-eyed, one is blue-eyed. Explain the results.

6. The offspring of a red petunia plant and a white petunia plant are found to have red stripes on white. Which explanation below is more likely to be correct?

- a. red is dominant; white is recessive
- b. neither gene is dominant nor recessive

QUICK TEST

1. Both Mr. and Mrs. Brown are good cooks. Their daughter, however, is not a good cook. *Being a good cook is a*
 - a. trait in the genes
 - b. part of learning
2. When red-eyed fruit flies are crossed with *red-eyed fruit* flies, all the offspring are red-eyed. For the trait for red eyes, both parents were
 - a. pure
 - b. hybrid
3. In another case, red-eyed fruit flies are crossed with red-eyed fruit flies. Some of the offspring are white-eyed, while others are red-eyed. The parents were
 - a. pure
 - b. hybrid
4. Experiments on mutation were carried on by
 - a. Gregor Mendel
 - b. Hermann Muller

FOR YOUR READING

The Earth for Sam, by W. Maxwell Reed, published by Harcourt, Brace & World, New York, 1960.

This is the story of the earth's past life. The book tells how mutations take place and how living things have changed through mutation.

ON YOUR OWN

Trace an inherited trait which is characteristic in your own family. For instance, you might trace the trait "dimples," or "red hair color."

Consult with your parents, and make a chart of your "family tree" as far back as they can remember. Indicate by the name of each person on the "tree" whether or not he or she possessed the trait.

Decide now what trait you plan to trace.

Why is it called a "family tree"? The chart really should look like a tree, with you as the trunk. The first two branches are for your parents; the next four are for your grandparents. There are eight branches for your great-grandparents, and so on, and so on.

CONCEPTUAL SCHEME

The universe is in constant change.

(Text pages 364–402)

UNIT CONCEPT

Nuclear reactions produce the radiant energy of stars, and consequent change.

A Preview of the Concepts

Unit Nine

STARS AND STARLIGHT

With this final unit in their text, the pupils arrive at an appreciation, the fullest possible at this level of study, of the capacities of the human mind to comprehend the immensity of the universe and the apparent order in its constant change.

A VIEW OF THE UNIT

There appears to be orderly change in the universe that man is able to observe and measure. The only constant seems to be change itself. These two statements are in apparent contradiction, but in this contradiction lies the fascination of science and of life itself.

The source of energy in coal and oil goes back to photosynthesis in green plants that existed many ages ago. And the energy for photosynthesis goes back to the sun. The sun's energy comes from a nuclear reaction different from fission studied in Unit Seven. This reaction is fusion—the combining of the nuclei of hydrogen atoms into helium with the release of energy. What is the relationship between fusion of atoms in our daytime star, the sun, and the food we eat? Matter is changed to energy and a portion of this energy is radiated across vast distances in space. And this energy is of the right amount to support life on this planet. Perhaps we accept this as not too surprising, but how is this constant supply of energy maintained? Pupils investigate this other type of nuclear reaction (fusion), and discover how combining of atomic nuclei releases a vast amount of energy. Matter, again, can be changed to energy, but the total amount of matter and energy remains unchanged. Einstein's prediction that $E = mc^2$ (page T-150) is found to apply. Thus, in Section 1, the pupils continue to enlarge upon the concept of energy change they have acquired.

The sun, however, is but one of the many bodies in space in which hydrogen is being changed into helium (and perhaps other elements). To understand the life of stars such as these requires knowledge of conditions (temperature, pressure) and processes (energy conversion) on the stars. A body must generate great forces to send radiant energy across vast distances in space. What relationship does the mass of a star have to its heat and to temperature? This heat-temperature relationship is found to be important, in Section 2, to the understanding of how large

a star may be. It is also an index, as is seen in a later section, of the age of a star and its energy potential.

Light from the stars can give us more information, other than the amount of energy they produce. Light can be collected from the far reaches of space, and we can tell with great accuracy the number of stars and the distances between them. So we gain understanding of the vastness of the universe.

Every so often, a startling and unexpected event happens somewhere in the universe. A star explodes! Why? How? Why are there not more of these events to be noted by keen-eyed astronomers equipped with light-gathering telescopes? What do these events mean? Even these events can be explained by the concepts of pressure and kinetic energy of particles of matter. Blow up a tire beyond the capacity of the outside wall to contain it, and it literally explodes, just as a supernova may explode. But the products form a new galaxy over eons of time. If the tire has a slow leak (compare with the earth's safety valve in a volcano!), it can be considered a model of the star that quietly subsides as its hydrogen is exhausted. Then the star becomes cold and invisible (not like the tire of course!).

Other knowledge—other evidence—is needed to understand our universe. How do bodies in space move? Where are they heading? We gain evidence from understanding the Doppler effect. The shift in frequency of light waves to the red end of the spectrum (Section 5) seems to indicate that many of the galaxies in the universe are rapidly rushing off into space. But the universe is not just one galaxy, but many; hence there are other motions to consider—elliptical; or orbital; as well as receding motion. Pupils finally put all these concepts together—fusion of hydrogen to helium with the production of energy, the number of stars, their motions toward or away from a center, their motions around a center, the dispersion of the mass of a star by explosion (novas and supernovas), and attraction or fusion of the products of these concepts evolve stars and star clusters—and from the combination of these concepts evolve a theory of the universe. It is obviously changing, and it's going to keep on changing. How can we face change with confidence? One simple reason—the changes are predictable, because we understand how, if not why, they take place.

If there were no change, the universe would be like the castle of "Sleeping Beauty" in the fairy tale. During the year the pupils have been studying change. In fact, this has been the theme of their science course throughout the grades. Change is the expected way of life—of all matter, of all living things, of the universe. Confidence in the future rests in understanding concepts of change.

SUPPLEMENTARY AIDS

All films and filmstrips are in color unless otherwise indicated. Those rated at junior high school level are somewhat more advanced in con-

Novas and Supernovas

The Constancy of Change

ceptual development, but suitable for most classes. Full names and addresses of distributors and suppliers are on page F-26.

Films

Outer Space (13 min., sound), Cenco, 1963. Describes the different kinds of stars, the color of stars, grouping in constellations and galaxies. How the telescope has given this information to man. (Intermediate)

The Sun's Energy (12 min., sound), Cenco, 1963. Energy released from the sun makes life possible on the earth. Today, through solar furnaces and other devices, man is seeking new and better ways to use the energy of the sun. (Intermediate)

Frontiers in Space (Exploring the Universe with Telescopes) (11 min.), E.B.F. Describes how telescopes work and shows the Hale Telescope, Mount Palomar Observatory, in operation; shows how data about the stars are obtained and analyzed. (Intermediate)

A Trip to the Planets (15 min.), E.B.F. Imaginary trip to planets helps us examine the composition and structure of our solar system; explains how the sun produces its enormous energy. (Intermediate)

The Sun and Solar System (12 min., sound), Cenco, 1963. Describes the workings of our solar system and the characteristics of the different planets; difference in size, number of moons, speed of rotation, and their atmosphere. (Intermediate)

Universe and Space (37 frames), McGraw-Hill, 1957. Explains the vastness of the universe as measured in light-years; luminous and non-luminous bodies, Milky Way galaxy, Newton's theory of gravitation. Pictures from Mt. Wilson and Palomar Observatories. (Intermediate)

The Stars and Outer Space (61 frames, sound), S.V.E., 1965. Colored photography shows the colors of stars; galaxies etc.; what is meant by light-years. (Intermediate)

The Moon and Its Relation to Earth (60 frames, sound), S.V.E., 1965. Explains why the moon has no atmosphere, its size and distance from the earth; what is meant by a gibbous moon. (Intermediate)

The Earth and Its Movements (53 frames, sound), S.V.E., 1965. Explains why the sun seems to rise in the east and set in the west; the rotation of the earth; movements of the bodies in the solar system. (Intermediate)

Mount Wilson and Palomar Telescopes (30 frames, black-and-white), E.B.F., 1961. Photographs show these telescopes and explain principle of reflecting telescopes. (Junior High)

The Universe in Color (50 frames), E.B.F., 1961. Color photographs show nebulae radiating tracers of red, blue, yellow, and green, as the gases are thrown off. Shows forming of supernova; explains light-year. (Junior High)

Nebulae (30 frames, black-and-white), E.B.F., 1961. Photographs from Palomar explain the variety of nebulae, bright and dark. Gives theory of how new stars are formed. (Junior High)

Filmstrips

Space Travel A.D. 2000 (52 frames), S.V.E., 1960. Shows that astronomy is to space travel as geography is to earth travel. Development of types of space craft; new forms of power under study—such as nuclear energy. What other worlds might be like and relative distances. (Junior High)

Conditions in Space Travel (35 frames), Jam Handy, 1962. Explains the difference between atmosphere and space; compares the effect in the atmosphere and in space of sound, moving bodies, light, and temperature; explains cosmic rays and Van Allen radiation belt. (Junior High)

Starred (°) titles are especially recommended for reading level and conceptual development. Other titles are good for special sections or guided readings. Names and addresses of the publishers are on page F-24.

°*Color in Your Life* by Irving Adler, John Day, 1962. An account of the basic parts of color and how it works. A thorough treatment of the subject with continuing reference to familiar objects and circumstances. Contains many diagrams and a color section for study of the phenomenon of after-image. (Advanced, but suitable as reference for average readers on selected topics.)

Discovering Chemistry by Elizabeth K. Cooper, Harcourt, Brace & World, 1959. An introduction to basic concepts of chemistry. Material is included on 30 common elements, atoms and molecules, formulas and symbols. Various investigations to be conducted in a home or school laboratory are described. (Average)

Experiments in Sound by Nelson F. Beeler, Crowell, 1961. The science of acoustics is explored by a variety of investigations. These are explained in terms of the theories advanced by similar experimentation by scientists. Practical applications of principles of acoustics are described. (Advanced)

°*Exploring the Sun* by Roy A. Gallant, Doubleday, 1958. Recounts man's ideas about the sun from his earliest superstitions to modern theories. Includes material on the birth and death of the sun, sunspots, prominences, and flares. The influence of the sun on the earth is described. (Average)

Fun With Chemistry (paperback) by Mae and Ira Freeman, Scholastic Book Services, 1962; distributed by TAB Books, a division of Scholastic Magazines; published by arrangement with Random House. Describes how to make a test-tube holder and other chemical equipment, including a measuring glass and a funnel. The rest of the book gives directions for 26 chemical investigations using hand-made and other simple equipment. Photographs accompany each investigation. (Easy)

°*Planets, Stars and Space* by Joseph Miles Chamberlain and Thomas D. Nicholson, Creative Educational Society, 1962; in cooperation with the American Museum of Natural History. Provides an overall perspective of celestial objects, from the earth to the outer galaxies. Full-page photographs, many of them from the American Museum-Hayden Planetarium, and the Mount Wilson and Palomar Observatories, help the reader to understand aspects of the universe he cannot see with his eyes alone. (Advanced, but suitable for reference by average readers on selected topics.)

Science Reading Table

The Stars by H. A. Rey, Houghton Mifflin, 1962. The first sentence states: "This book is meant for people who want to know just enough about the stars to be able to go out at night and find the major constellations, for the mere pleasure of it." The rest of the book describes a new way of mapping the night sky and of finding one's way about in it. (Advanced)

°*The Sun* by Herbert S. Zim, William Morrow, 1953. Describes size, temperature, source of energy, sunspots, and coronas of the sun. Man's dependency upon the sun for food and energy is included. Many illustrations assist in explanation of known facts and theories. (Advanced)

► INTRODUCING THE UNIT

How many stars can you see on a clear night? You can't count them, but make a guess. (About 2,500 will be pretty close.) How many stars do you think you could see with the largest telescope—or with a radio telescope that can "hear stars" because of the radioactivity they give off from nuclear reactions in them? The answer will surprise you—over one hundred billion in our Milky Way galaxy, not counting other galaxies that may be even larger. What is a star? Can you name one that is important to you? Of course, it's the sun, as every pupil should know. How does the sun compare with other stars? Larger? Smaller? Hotter? Cooler? How far away do you think the other stars are? How do they move—or do they? Are all these stars and galaxies in the universe always the same—or are they changing? How do we know?

All kinds of hypotheses are likely in answer to such questions as these. Come back to the hypotheses at the end of the unit, or encourage revision of hypotheses and theories from time to time by asking: Do you still think that . . . ?

(Text pages 366–71)

SUBCONCEPT

Nuclear reactions are the source of the sun's energy.

Processes emphasized

Observation and analysis

Investigation (with design of experiment)

Hypothesizing

Theorizing

Prediction

Development of models (mathematical and theoretical)

Section 1: ENERGY FROM A STAR

The pupils begin their study of changes in the universe by studying fusion, a nuclear reaction in which matter is converted into energy as nuclei of atoms combine to form nuclei of another element.

Introducing the Concept

Hold up a glass of water and a lump of coal. Which of these is a fuel? The answer is obvious, but let us look at these and think about them a little more closely. What happens when fuel burns? (It combines with oxygen.) What substance do we get then? (Carbon dioxide.) What is water made of? (Hydrogen and oxygen.) We got a gas from burning coal. Do you think we could get water from burning hydrogen? After all, oxygen is combining in both cases. Where can we get some hydrogen to find out? Let us do the investigation on text page 367, and then investigate some new questions, as on the next page.

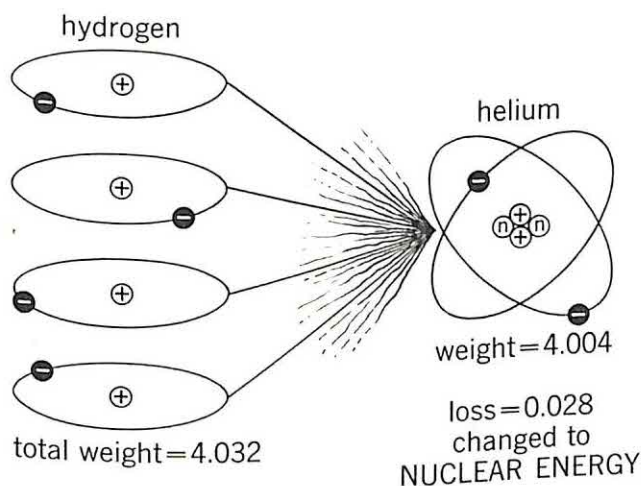
We can take atomic nuclei apart (Unit Seven); can we put atomic nuclei together? If so, what do we get? A different form of matter? Energy? Or both?

Developing the Concept

Hydrogen in a chemical change. The investigation suggests using dilute sulfuric acid. It would be best to prepare only a small amount in advance, since handling of concentrated sulfuric acid or having it where it can be accidentally tipped over is not recommended for the elementary school classroom. You may use, instead, a small amount of sodium sulfate to provide the conductivity needed for passage of the electric current through the apparatus. After pupils have tested the second test tube for oxygen with a glowing splint and have noted that it bursts into flame, you might ask: Is the oxygen burning? Pupils should be sure to understand that the oxygen is not itself burning, but that it combines with hydrogen in one instance and with carbon in the wood in the other; that is, that oxygen supports combustion during oxidation.

If pupils are not familiar with chemical formulas, help them see that H_2 and O_2 indicate that 2 atoms have combined to form 1 molecule of the compound. In a chemical change only electrons are involved.

Chemical reactions and nuclear reactions. Where have we studied nuclear reactions before? (Unit Seven—splitting of uranium.) What kind of reaction is this? (Fission. The nuclei have been split apart.) Do we get the same amount of matter in this reaction? (No. There has been a loss in the combined atomic weights; a loss of mass.) It may be useful to review the New View section beginning on page 321 (see also page T-149). Place the following diagram on the board, adding the numerical values as you bring out the concept of fusion through discussion.



Pupils will note that 4 protons from the 4 hydrogen nuclei have become 2 protons and 2 neutrons in the helium nucleus, and that 2 electrons

Atoms combine to make molecules in a chemical change; molecules can be separated into the elements of which they are composed.

Equipment and Materials

... sodium sulfate

In nuclear reactions, the nuclei of atoms are divided (fission) or combined (fusion).

Great energy starts a fusion reaction; great energy is released.

In a fusion reaction, some matter is converted to tremendous energy.

have disappeared. These tiny particles have become a form of energy, but the amount is not significant because of the extremely small mass of an electron. In fusing, the hydrogen atoms produce a tremendous amount of energy. Why is hydrogen sometimes called the fuel of the sun?

How can fusion take place? No matter what you do in a laboratory, you can't get hydrogen nuclei to fuse. It has been done on earth only in the hydrogen bomb, and a fission reaction was necessary to start it. A fission explosion may generate as much as 100,000,000 degrees of heat. Somehow this heat causes hydrogen nuclei to fuse. (Because heat energy triggers fusion, fusion is often referred to as a *thermonuclear reaction*.) A great deal of energy has to be put in. Where does this energy come from? Pupils should recall that some of the matter of a fission explosion is converted to a tremendous amount of energy (heat energy and radiant energy). In a fusion reaction, matter is also converted to energy. How do we know? What are some of the things that the sun's energy makes possible on the earth, even though we receive around one billionth of this energy? (Photosynthesis, evaporation, even sunburn!)

The mathematics of fusion. If you have placed the diagram on the board, page T-181, you may wish to place the atomic weights (mass units) under the representations of the atoms, as the pupils give them to you. The atomic weights are given in the diagram in decimals to three places. If pupils do not understand decimals, you may wish to translate into hundredths and thousandths as you write the figures on the chalkboard. With less able pupils, it may only be sufficient for them to see that the figures are larger for 4 atoms of hydrogen than for 1 atom of helium.

Has matter been lost? Has energy been gained? Is the total of both the same after a fusion reaction? Place Einstein's formula, $E = mc^2$, on the chalkboard, in review of the New View section (see page T-150). Scientists, after careful calculations from evidence they have obtained by using delicate measuring instruments, have found that the amount of energy gained is almost exactly equal to the figure arrived at by substituting the mass lost for m in the formula.

Some pupils may ask: How long will the sun last? The sun loses about $4\frac{1}{2}$ million tons of its matter every second in producing energy, but 15 billion years from now the sun will still have 99.9 per cent of its mass.

Extending the Concept

Fusion models. Cutouts may be made to model the diagram on text page 369. Or a three-dimensional model may be made with Styrofoam balls and wire. Encourage inventiveness in the representation of energy given off by the reaction.

Heavy water. Hydrogen has three isotopes: regular hydrogen, deuterium (with 1 neutron), and tritium (with 2 neutrons). Interested students may investigate in reference books why knowledge of "heavy water" was an important secret in World War II. How did Dr. Harold Urey contribute to knowledge in this area?

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. a 4. a 5. a 6. b

Using What You Know. 1. Fission is the splitting of atomic nuclei; fusion is the combining of atomic nuclei. a. Fission. b. Both; fission triggers the fusion reaction. c. Fusion. 2. a. This is a chemical reaction. b. This is a nuclear reaction in which some matter is changed to energy.

Section 2: THE TEMPERATURE OF A STAR

By investigating common phenomena, pupils gain insight into inferences that can be made about the heat, temperature, and size of bodies in space that emit radiant energy.

Introducing the Concept

Turn on the electric hot plate and watch the colors of the heating element change. What do the changing colors tell us about the amount of heat? If you have a Bunsen burner, adjust the flame so that it is yellow. When we adjust the burner, why do we try to have a blue flame? (Blue flame is the hottest.) Combine both these observations by holding a length of many-stranded picture wire over the yellow flame (use pliers!) and noting the color of the wire. Now heat it in the blue flame and note the color. Let the wire cool in a bucket or box of sand. Pupils should infer that a color toward yellow or orange indicates a lower temperature than a color toward blue or blue-white.

How can we use light and color to gain information about the stars?

Encourage pupils to suggest hypotheses before reading the text and performing the suggested investigation.

Developing the Concept

Light and temperature. What is the speed of light? Pupils may recall that it is 186,000 miles per second. What form of energy have we already studied that travels at the same speed? (Electromagnetic waves in our study of radio and television.) Did these waves have the same wavelength and frequency? (No; short waves had higher frequency and long waves had lower frequency.) Recall that we could separate the waves by frequency in a radio set.

Ask a volunteer to design a way to send light through the prism to obtain a spectrum of colors. What can you infer about light? (It is broken up into bands of colors; each color has a difference in frequency.) Pupils who have studied *Concepts in Science 5* will have already studied this characteristic. A copy for review and reference will be useful on the science reading table.

A glowing substance seems to "broadcast" on a particular wavelength or on a particular frequency band. If, for example, your radio set is tuned in at 880, you can find the name of the station in your local news-

(Text page 371)

(Text pages 372-80)

SUBCONCEPT

The heat, temperature, and size of a star can be determined by analysis of its light.

Processes emphasized

Hypothesizing
Theorizing
Observation
Analysis of observations
Library research
Measurement
Investigation (with design of experiment)

Equipment and Materials

... short length of picture wire
... pliers
... sand

Analysis of light from a star helps us determine its composition and temperature.

paper. Similarly, if you know where certain lines appear in the spectrum, you can identify the substance—or substances—in a star that is sending light to your spectroscope. Because substances on earth give the same spectrum when they are heated until incandescent, we are certain of our identification. The “broadcast bands” appear not to change. Ask pupils to study the spectra on pages 372–73. What does the brightness of the spectrum tell us? If you have colored chalks, a model of the spectrum may be placed on the board. Have pupils point out which section will be brightest for Antares, Deneb, and the sun. The surface temperature of another star, Aldebaran, is less than that of the sun. Where will its light show brightest? (Toward the red end, but not as far as Antares; it is an orange star.) Vega, one of the bright stars in the night sky that shines with a bluish light, would show its temperature near what end of the spectrum? What about Algol’s twin (page 374)? With a light bulb and a tennis ball, can a pupil model how Algol appears dark about every three days? What event is this like that we sometimes see from earth? (Eclipse of the sun.)

A star’s heat and temperature. What is the difference between heat and temperature? Allow pupils time to form hypotheses before they proceed with the investigation on page 375. If some pupils are unconvinced that heat energy has been given up by the water to melt the ice cubes and that the number and speed of molecules in motion determines the heat energy, you might try using an obvious source of heat. Place a pan with about a pint of water from the tap over a source of heat. Take the temperature at the end of a fixed time; say 2 minutes. Place a larger amount of water, also from the tap, in another pan; place it over the same source of heat, and time it carefully for 2 minutes. Take the temperature. Which has the lower temperature? The same amount of heat has been put into giving the water molecules kinetic energy. What inference can we draw? (If the temperature is lower for one object than another under the same conditions, the object with the lower temperature must have the greater number of molecules; i.e., the greater mass.) How does this apply to measuring the size of stars? Pupils may still have difficulty drawing the inference without further assistance. How does a star get its energy? (Fusion.) How do we know its temperature? (From its color.) Since stars get their energy in the same way—by nuclear fusion—a star with a lower temperature is likely to have the greater mass. To find another relationship useful in calculating size of stars, pupils may perform the investigation on text page 377.

How big is a star? If we know how much energy (heat and light) a star gives off and what its temperature is, we can find out the size of the star. This is fairly easy to demonstrate. Volunteers may help cut out several pieces of foil 1 inch square and perform the demonstration. Pin one square on a dark background and hold it so that it reflects sunlight toward a light meter. Record the reading. Repeat, adding a square at a time and at the same distance, until you have four readings. You should

The heat energy of a star is a clue to its size.

Equipment and Materials

- ... hot plate, or other heat source
- ... 2 pans
- ... thermometer

(See also the Teacher’s Manual for Classroom Laboratory 6.)

The total heat and light energy of a star is a further clue to its size.

find the readings increase in direct proportion to the number of squares. The brightness of a glowing body depends on its total surface. The more light, the larger the surface.

You can also demonstrate that a red star, like Antares, gives off less energy than a yellow star, like the sun, by measuring the difference in light energy from different colored Christmas tree bulbs. Students may compare visually, and check their impressions by obtaining a light-meter reading. Can the pupils see how the total light energy collected and a knowledge of the temperatures can be used to calculate the total area?

Extending the Concept

Learning more about spectroscopy. Children interested in building a simple spectroscope, may write to Edmunds Scientific Company, Barrington, New Jersey, for information. A number of interesting investigations can be made with replica (diffraction) gratings. See also page 619 of *Exploring the Sciences* (page F-23).

Locating stars. Pupils interested in recognizing the major stars should be referred to library references which contain star charts. Many junior high school textbooks have a section on astronomy.

Using parallax for measurement. A phenomenon known as parallax, the seeming change in the position of a star due to a change in position of the observer, can be used to measure distances. For additional details and illustrations, see *A Sourcebook for Elementary Science*, pages 158-60.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. b 5. b 6. a 7. a

Using What You Know. 1. Fusion of hydrogen into helium. 2. Algol is a bright star; it has a twin star that gives off little light; when the dark star revolves between Algol and us, the bright star is masked. 3. Probably they do not have enough hydrogen for fusion reaction.

On Your Own. 1. $\frac{\text{Distance to card}}{\text{Distance to object}} = \frac{\text{size of card}}{\text{size of object}}$, or $\frac{d_1}{d_2} = \frac{s_1}{s_2}$
2. Yes, measure the diameter of an object that just masks a star; measure the distance of the object from the eye; only one distance is unknown.

Section 3: NUMBERS OF STARS

The pupils infer a way for estimating the number of stars by investigating the method of sampling. They also gain further understanding of one way in which great distances are measured with accuracy.

Introducing the Concept

Place on your desk a quart or half-gallon jar or a round fish bowl filled with marbles, beans, grains of corn, or some other easily countable

Equipment and Materials

- ... aluminum foil
- ... scissors
- ... light meter
- ... black background
- ... colored Christmas tree bulbs

(Text pages 379-80)

(Text pages 380-86)

SUBCONCEPT

The Milky Way galaxy is vast in the number of its stars and the distances between them.

Processes emphasized

Measurement

Design of investigation (statistical measurement—sampling)

Development of models (mathematical and theoretical)

Hypothesizing

Theorizing

Prediction

Equipment and Materials

... jar or fish bowl

... marbles, beans, or other easily counted objects

The number of stars is estimated by sampling regions of a galaxy.

Equipment and Materials

See textbook page 382; also the Teacher's Manual for Classroom Laboratory 6.

objects. State that we are going to find out how to count the stars in the sky by devising a way to count the objects in the jar without taking any of them out. Guessing is not allowed. You may touch, or lift, or use any kind of instrument you wish, but you must come up with a plan. Have on hand a few objects like those you placed in the jar for a pupil to measure, if he includes measurement in his plan. Allow time for the pupils to think of a plan and to work it out, provided all the pupils are engrossed. Only you know the number of objects in the jar (you counted them the night before when you put them in!). Do not reveal the number until after pupils have completed the section. The nearest number, worked out on the basis of a pupil's plan, wins the prize (praise—or a minor reward, if you wish). The key questions are:

How large is the Milky Way galaxy? How many stars are there in it? How do we know?

Developing the Concept

How big is 100 billion? The first star catalog made in A.D. 150 by the Greek, Hipparchus, listed just over 1,000 stars. How do you think it is possible for scientists to estimate a count of 100 billion? This is the number of stars—approximately—in our galaxy. What tools have made this count possible? (Telescopes, cameras, spectroscopes, radio telescopes, and many others.) We can't count stars by pulling them out of a jar one after another, so how do we know? Plunge the pupils immediately into the investigation on text pages 382–83. (They're probably itching to know if their plan for estimating your jar is on the right track.) They will also want to try the additional investigation suggested. When the concept of sampling seems fairly well established, you might say: You had only 300 seeds to count in your investigation; could you count the stars? Do you always see as many each time you look? Are they in the same place at each time and each night? (Some pupils may never have looked at the stars to see the many nighttime changes.) Do you see as many stars on a moon night as on a dark night? What happens if it is cloudy? Such questions as these tend to point up the difficulty of counting the number of stars in our galaxy.

What do you do if you want to record what was happening at a particular time? Or at a particular place? (Photograph the scene.) What devices enable us to take photographs of the stars? (Telescope and camera.) What one condition is needed for taking a photograph? (Light.) What provides the light for taking photographs of the stars? (The fusion reactions in the stars; hence, the light energy will cause a change in photographic film which we can see.) While the text does not answer these questions, pupils will be able to put concepts together from earlier work or from their own experiences to develop reasonable explanations.

How does the concept of sampling help us count the stars in the Milky Way? (We can take photographs, count the pinpoints of light, and make a good "guess.")

Boundaries for a sampling? If you count only the number of objects you can see against the glass in the jar with which we started, how accurate do you think our estimate would be? What other measurements are needed? For example, how do you measure the number of cubic inches of sand in a box? (Length, breadth, and thickness.)

How can you measure the thickness of the Milky Way? How far across is it from side to side?

Remember you are inside the "box"—inside the Milky Way. To find the volume of the Milky Way, you would have to measure out to the edges, would you not? In how many directions would you have to take a sampling? (At least four.) Now, imagine you are in an airplane flying over a city at night. The city is in a long narrow valley. Near one end of the valley you see the central lights of the city thickly clustered in one direction, and fewer lights in the opposite direction. There are still fewer lights on either side. If you have imagined well, you have a mental picture, a model of the Milky Way galaxy. In your plane, you are flying (well up the valley), to about where the solar system is in relation to the rest of the stars in the Milky Way galaxy; that is, about two thirds of the way toward one end. If you look at the part of the summer sky where there seems to be a band of thickly clustered stars, you are looking toward the end of the "valley" where most of the "lights" are. Draw on the chalkboard an outline of a long flat cookie with a large raisin in the middle. Ask a volunteer to locate the solar system and fill in the cookie with "sugar granules" to represent stars. From where the earth is located, what kind of sampling would you get if you took photographs in different directions? (The count of stars would vary greatly in each photograph.) In spite of these difficulties, astronomers have been able to use sampling to calculate the number of stars in the Milky Way galaxy, as indicated on text page 385. Many samplings were taken by many astronomers and then an average taken.

Now is a good time to ask whether the pupils would like to revise their procedure for counting the number of objects in the jar with which the lesson began, or whether they would like to see how close their estimate came. Was one method proposed better than another? Why?

Can we count the stars as they are today? How long would it take you to drive to the nearest town? How long to go to the farthest coast? Probably no two persons would agree on the number of minutes or the number of hours, but all would agree it would take time. If everyone drove at *exactly* the same speed, would there be any difference in time? (No.) How fast does light travel? Does this speed vary? (No, not in space.) This, or a similar analogy, provides a model for measuring distance, since the speed of light and the number of minutes in an hour do not vary. Why do you think astronomers use the light-year as a measure of distance between stars? (Both measurements do not change, and the numbers are smaller to work with.) Why do we say that we can never count the stars as they are today? Pupils, from the information given, can

In order to estimate the total number of stars in the Milky Way, we must determine the galaxy's dimensions; the light-year unit of distance is convenient.

We see the solar system and the galaxy as it was in the past.

infer that our count of the stars is based on whether the light from them has traveled far enough to be gathered by the collecting lens of a telescope. In these ways—and perhaps others—the pupils recognize the difficulties of describing our changing universe; but they must surely infer that the universe is in constant change.

Extending the Concept

Graphing the galaxy. The Milky Way galaxy is about 15,000 light-years across at its thickest part from side to side, and about 100,000 light-years from end to end. Using a scale of $\frac{1}{4}$ inch equals 1,000 light-years, diagram the Milky Way galaxy on squared paper. The central portion can be represented as somewhat egg-shaped, tapering to the long ends like two arms of a pinwheel. Locate the sun, center of the solar system, and fill in the outline of the galaxy with dots to represent stars. For realism, use several colors of crayons to *imagine* red stars, orange stars, yellow stars, and bluish-white stars.

Orbiting Space Observatory (OSO). Why are space scientists orbiting satellites to study the stars? What effect does the earth's atmosphere have on light from space? Interested pupils may try to locate the most recent studies about bodies in space. The National Aeronautics and Space Administration (NASA), Federal Office Building No. 6, 400 Maryland Avenue, S.W. Washington, D.C. 20025, may be able to supply information. (Use school stationery for requests.)

Radio astronomy. Newspapers carry reports from time to time of new "big dishes," radio antennae that capture signals from orbiting space capsules or from stellar radiation. For details, ask the school or local librarian if she has a copy of *The Big Dish*, by Roger Piper, Harcourt, Brace & World, 1963. Report on what radio telescopes reveal that light telescopes do not. (There is a parallel here between the light microscope and the electron microscope.)

(Text page 386)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. a 4. b

Using What You Know. 1. a. Sampling. b. Count the number of gopher holes in a certain number of acres (ten perhaps) and multiply by 1,000. 2. a. 4 months. b. January 1 (approximately), 1972; but this is impossible because anything as small as a football field could not be seen at such a distance.

(Text pages 387-92)

SUBCONCEPT

Stars are continually changing.

Section 4: THE HISTORY OF A STAR

The pupils gain greater understanding of the changing universe as they study the history of the sequence of changes in a star as its matter is converted to energy.

Introducing the Concept

When light-weight particles are evenly mixed with heavy-weight particles and shaken together, do the particles stay together, or do they separate? Mix about equal amounts of fine-grained sand and small pebbles, or BB shot, together and place the mixture in a glass jar (it need be no larger than a baby food jar); agitate the particles in the jar. Where do the heavier particles go? (Toward the bottom.) Recall that carbon dioxide in air is heavier than air, while oxygen is lighter than air. If you wanted to pour oxygen, how would you do it? (Upward.) Carbon dioxide? (Downward.) The force of gravitation appears to act to separate heavier particles from lighter and attract them toward the center of the earth.

Now imagine that hydrogen in a star is gradually changing to helium. What do you think is happening to the heavier helium? On what do you base your hypotheses? (Pupils should recall that addition of neutrons and protons to the nucleus of an atom increases its atomic weight.)

What happens in a star as more and more of its hydrogen is converted to helium?

Developing the Concept

Temperature and pressure. Pupils are familiar with the effect of heating a gas; it expands. A balloon tied over a jar of air will expand if the air is heated. They may also recall that heat energy increases the speed of molecules of water so that they change state and become steam. In studying nuclear reactors, they also learned that under pressure, water remained in liquid form, but the temperature in the heat exchanger was greater under pressure. The pupils should make careful observations of the investigation on text page 389. What happens to a gas when its molecules are pressed closer together? (Their energy becomes greater, just as the energy of a spring becomes greater when it is compressed.) What happens if more and more molecules are packed into the same volume? (All the molecules have the same kinetic energy, but this energy is multiplied and the temperature increases.)

After reading up to "A Star Explodes," the pupils may be able to infer that the concentration of helium nuclei near the center of a star is like packing 4 atoms in the place of 1, with the result that temperature increases. If temperature rises, the pressure is increased. So long as this pressure is under control, the star keeps on using up hydrogen to make helium and gives off energy at a steady rate. If the internal pressure of an automobile tire gets too great, what happens? (A blowout.) Pupils, if they follow the reasoning closely, see that a nova is somewhat like a cosmic blowout.

Most stars age quietly. Three supernovas and perhaps 60 to 80 novas have been recorded. Why haven't there been more, since the Milky Way galaxy alone has over 100 billion stars? If you increase the pressure inside a balloon, what happens? Of course, it swells up. Many stars, it is

Processes emphasized

Building of models
Hypothesizing
Theorizing
Prediction
Library research
Reporting
Speculation

Equipment and Materials

... glass jar
... sand
... pebbles or BB shot

An increase in pressure raises temperature, and a rise in temperature increases pressure.

Most stars undergo gradual change.

thought, do this and become red giants. What happens then to the temperature? (It becomes less—but the heat energy is the same—as the pupils should recall from Section 2.)

The red giants continue to use up hydrogen, and gradually shrink, much as an automobile tire gradually collapses with a slow leak. As they shrink, the gases are compressed again and the temperature increases. The stars become white dwarfs which gradually cool, much as the filaments of a hot plate cool when the current is turned off. (Some stars may expand and contract in this manner more than once.) These stars eventually use up their hydrogen fuel and become dark. Without light, we can no longer see them. Without energy that creates electromagnetic waves, we can no longer “hear” them with the big-dish-type antennae that collect electromagnetic emissions.

Systems of stars may have formed from supernovas.

Origin of the earth and the solar system. As pupils read “The Stars—As Factories,” encourage speculation of how the solar system formed. Since we are inside the solar system, we cannot take a picture of it (it has been plotted, however, by a radio telescope); but there are other similar star systems that have likenesses and differences that we can examine. The text mentions the Crab Nebula, and pictures it on page 390. Pictures of other nebula may be used for comparison if you have them available. NGC 3031, in the constellation of Ursa Major, shows how the arms of the pinwheel-like form of a nebula are beginning to narrow and break up into small star clouds. Another nebula, also in Ursa Major, NGC 5457, shows the arms with condensed brilliant star clusters. Another star cloud is NGC 598, in the constellation of Triangulum, in which star clusters and individual stars predominate, with only a trace of two spiral arms stretched out to form an almost straight line. The magellanic clouds, visible only in the southern hemisphere, have no trace of a spiral form. These pictures show the possible course that a supernova may take, if the theories are correct. A price list of star photographs, wall charts, and a popular magazine, *Sky and Telescope*, is available from the Sky Publishing Corporation, Harvard College Observatory, Cambridge, Massachusetts 01922.

Encourage hypotheses on the formation of elements and the origin of star systems. It would be useful to follow up with a free reading period, using books on the science reading table or in the school library.

Extending the Concept

A moving-picture history. From what they know of stars and atoms, galaxies and star clusters, astronomers can now describe the history of the universe somewhat as follows:

1. Perhaps 15 billion or even more years ago, the universe may have consisted of more or less concentrated masses of hydrogen spread unevenly through space.

2. Knowledge of the force of gravitation suggests that gigantic swirling clouds were formed as thicker masses of hydrogen pulled on the thinner masses.

3. As these clouds contracted, they moved apart and began to spin, the thicker clumps of gases tugging at the thinner ones.

4. The thinner clouds broke up and the thicker ones grew denser to become stars and star clusters.

5. Each giant cloud became a spinning pinwheel or spiral nebula.

Interested pupils may wish to make a wind-up scroll or movie sequence of these events. Draw each stage and paste in sequence on a roll of shelf paper. Cut a slot the width of the shelf paper on both sides of the carton. Draw the paper through the slots as the narrator tells the story. Use doweling or old rolling pins for the wind-up spools. A sequel may show the explosion of a star (a nova) to form a spiral nebula.

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. b 4. a 5. a

Using What You Know. The fusion of different particles as a supernova begins to cool. Heavier and heavier atoms are gradually formed until most of the elements we know have been made.

Section 5: MOTIONS OF THE STARS

The pupils re-examine concepts of wave motion in order to infer the position and motions of stars. They also examine how changes in position can be predicted.

Introducing the Concept

Have you ever heard an automobile horn in the distance and said, "It is coming toward us." Or a jet plane in the sky, and said, "It is flying east" (or in another direction). How did you know? Was it just that it sounded louder? Or did you notice anything else about the sound? The more observant pupil will probably answer that the sound was higher when it was closer, and lower when it was farther away.

But we can't hear stars. What has sound to do with stars?

How can we tell in which direction stars are moving? How can we use this knowledge to predict where a body in space will be at a given time? What reasonable theory about the universe can the motion of the stars help explain?

Developing the Concept

The Doppler effect. How does sound travel? Pupils know that it travels in a back-and-forth motion through any medium except space. It travels in a wavelike motion at a speed of 1,100 feet per second (in air at normal temperature and air pressure). The equation, as your pupils may have learned in Unit Seven is:

$$\text{Speed (or velocity)} = \text{wavelength} \times \text{frequency}$$

Equipment and Materials

... carton

... shelf paper

... doweling, or rolling pins

(Text pages 391-92)

(Text pages 392-96)

SUBCONCEPT

The position of the stars changes in a predictable and orderly way.

Processes emphasized

Observation

Analysis of observations

Hypothesizing

Theorizing

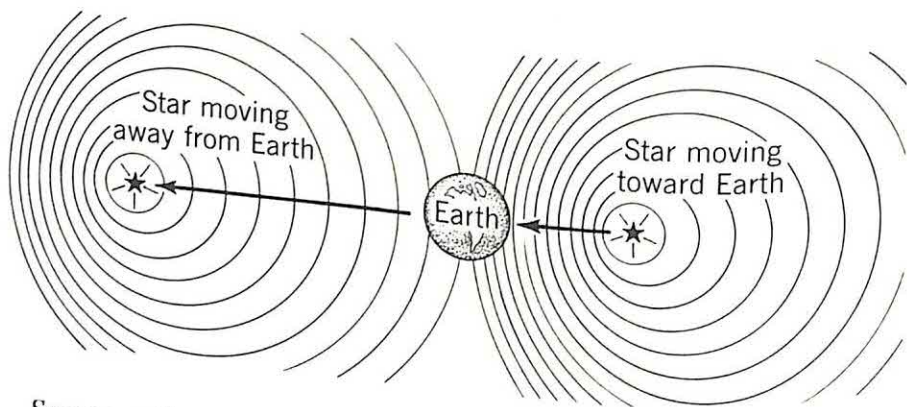
Library research

Prediction

The direction of a moving object can be determined by wavelengths of light or sound.

If the wavelength becomes shorter, what happens to the frequency of sound waves? (The frequency is greater; that is, there are more waves in a given distance in a given period of time.) What happens to sound when the frequency becomes greater? (The pitch becomes higher.) The Doppler effect, because it bunches up sound waves, has the effect of shortening the wavelength and, hence, increasing the frequency, or pitch. The reverse is also true. This is the reason that it is easy to predict the direction in which a jet plane is traveling or whether an unseen automobile is approaching or going away. (The effect is clearly stated in a mathematical equation beyond all but a high school student in physics.)

What other kind of waves have we studied? (Electromagnetic waves.) What is the constant speed of these waves? (186,000 miles per second.) Are light waves electromagnetic waves? (Yes.) What changes take place in light waves if they become shorter? (Their frequency is increased.) If they become longer? (Their frequency is decreased.) How can we recognize this change in frequency? (The high frequencies are at the violet end of the spectrum, and the low frequencies at the red end.) If a star's spectrum is shifted toward the red end, which way is the star moving? To further develop understanding of the Doppler shift, you may wish to place the following diagram on the board, using it for pupils to illustrate how motion toward or motion away can be inferred.



Some pupils may be confused between red giants discussed earlier and the Doppler effect of the red shift, indicating that a star is moving away. A laboratory spectrum of an element on earth that is also known to exist in a given star is compared with the spectrum of the star. Any shift of the position of the element toward the red end tells the astronomer that he is dealing with the Doppler effect and not with temperature.

Predictability and change. We have stars moving away from us, we are moving around the sun, the solar system is turning around the center of the Milky Way galaxy, as galaxies do, and to further complicate matters, we have comets that come and go. How can we make any sense out of this continual change and continual motion? How can we ever predict where any star will be?

The changing positions of bodies in space can be plotted with accuracy.

If you have enough space in the classroom, one pupil may walk in a small circle around an object—in an orbit. If another pupil traces a larger orbit, starting at the same time as the first pupil, will he be in the same position in relation to the central object and the first pupil when the first pupil has completed one full orbit? After you know how fast each pupil walks and the length of each object, could you predict where the pupils will be on another trial? Both walked in an orderly manner in an orderly path; hence, prediction is possible. You predicted on the basis of speed and distance, did you not?

If you see two planes traveling in the same direction, what will you need to know to be able to calculate which is flying the faster? (Distance of each from you.) If you know how fast the planes are flying, you can also calculate the distance. One measurement is a function of the other. Astronomers can compare photographs over a period of time to calculate speed of stars and their distance, if they know how far away another star is in their photographs and how fast it is traveling.

What else do we need to know to predict where a body in space will be at a future time—or where it was in the past? If pupils do not volunteer “the direction it is moving” or “its orbit,” ask: What kind of a line does a moving star trace in the sky? (Curved.) Then: If you know part of the path of an object, can you predict the rest of it? You might prepare ellipses of various shapes, ranging from a short ellipse, such as the earth’s around the sun, and a long ellipse, such as Halley’s comet, and then cut off arcs of the ellipses. Display an arc and call for volunteers to complete it while others act as critics. Practice with other arcs until orbit prediction seems understood.

Stress that scientists seek orderly explanations of the changing universe. The theories of the universe are based on what appear to be orderly changes. Increase or decrease in speed is part of this order. The orderly path a body follows is another part. But also stress that evidence is still incomplete and that our concepts can change; however, the large concept that the universe is in constant change is unlikely ever to change.

Extending the Concept

The origin of the universe. There are various theories of the universe. The textbook mentions one that many scientists hold. Recently, some scientists have proposed that the universe will expand at an increasingly slower rate, come to a standstill, begin to collapse on itself, and start contracting. Finally, the universe will annihilate itself and a new one will start from the fragments. The cycle is supposed to take about 80 billion years. The universe is thought to be some 15 million years old at the present time. Fred Hoyle, the British astronomer, advances the steady state theory; George Gamow and George Le Maitre, the evolutionary theory. Interested pupils will find these and other theories an engaging area of library research.

Equipment and Materials

... prepared arcs of ellipses

(Text page 396)

(Text pages 397-402)

CONCEPTUAL SCHEME

The universe is in constant change.

UNIT CONCEPT

Nuclear reactions produce the radiant energy of stars, and consequent change.

How do we know?

Comets. Halley's comet will return in 1986. How can this be predicted? How many comets have been sighted? What are comets? How many can we predict seeing again? The *World Almanac* is one source for data about comets, eclipses, meteor showers, and other astronomical events.

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. a 4. a

Using What You Know. 1. The car was moving away. 2. It is moving away, because the Doppler effect causes a shift to the end of the spectrum at which the frequencies are lower.

Section 6: THE MAIN CONCEPT: THE CHANGING UNIVERSE

The pupils, in review, summarize the diversities of change in the universe and realize that there is a pattern of constancy in these changes. A repeating pattern, even though parts are constantly changing, provides an order which, if the concepts are understood, enables us to analyze events of the past and to project events into the future.

CONCEPT SUMMARY

Bases for prediction. Encourage pupils to locate Polaris, the North Star. It is always in the same location at the same elevation above the horizon as the latitude of the town in which they live. Although Polaris "wobbles" somewhat over several centuries, it is sufficiently fixed to be a point around which the motions of other bodies in the solar system can be mapped. Polaris stays in the same position in relation to the earth, to all intents and purposes, but the stars and constellations seem to move counterclockwise around Polaris from night to night and from season to season. Why is this so? Encourage the pupils to recall that the earth is rotating, with its axis pointed at the North Star. This rotation causes an apparent change of position. The earth is also revolving around the sun. Compare the motions with that of a visible man-made satellite. Once every 90 minutes or so, it might be possible for us to see the satellite in a different position in relation to the stars. If an astronaut is in an orbiting capsule, he will see all the countries over which his capsule passes in the same 90 minutes of orbit. Pupils should enlarge their understanding from these or similar analogies, that a star's position as we see it from the earth is determined by its relationship to other bodies in space.

Pupils, if they have not already done so, should reach the inference that there is an ordered regularity to the motion of bodies in space, and that if we understand this orderliness, we can predict from the components of motion that give order. Similarly, knowing that fusion of hydrogen into helium takes place at a certain rate, we can predict the amount

of energy given off by a star. We can also understand novas, but we cannot predict their occurrence.

Order in change. How do we discover the ways things work? The obvious answer that we discover by investigation is not enough. Stress that a hypothesis must be checked and rechecked, that observations must be checked and rechecked before we can form a theory, that a theory also must be checked and rechecked against all the hypotheses that supposedly support it. Only after long sequences of tests can we say that there is a law by which events take place. Have you heard the phrase *law and order*? In science, *a law indicates that there is a perceptible order*—perceptible to man—that changes follow certain sequences of events, and that the sequence is predictable within a very small margin of error.

As the pupils read and discuss this final section of the final unit of the textbook, encourage listing of hypotheses, theories, and laws. Why is the concept of an expanding universe considered a theory? What other laws and theories can be cited? And which is which—with supporting evidence?

The constancy of change. Can you think of anything that does not change? Anything that is not changing in some way at some time? List the changes you have studied in this unit. Do they follow a pattern? What is the pattern? What is the relationship between changes or between patterns? Are some patterns repeated; that is, are there cycles of change? (Pupils may be encouraged to draw on their other work of the year to illustrate cycles of change on the earth or in the universe.) The answers are in the text or this Teacher's Edition, but in one sense all answers are open-ended, for all the evidence is not in. It may never be in—certainly not in the lifetime of the pupils. Whether a pupil is likely to become a scientist or not may be indicated by the degree to which he questions evidence. Without change, he could not raise questions!

FIXING THE MAIN CONCEPTS

Testing Yourself. 1. d 2. b 3. b 4. d 5. a 6. b 7. c 8. b

Quick Test. 1. b 2. a 3. b 4. a 5. a 6. c 7. a 8. a 9. b 10. a

A CONCEPT OF CHANGE: A NEW VIEW

In many ways, this final New View is a pulling together of all the concepts and subconcepts the pupils have been studying over their years in elementary school. They have been uncovering concepts through investigation, formulating and testing them, and finding that to all appearances there is order in a constantly changing pattern of objects and events.

Matter changes from one state to another, from one form to another; it combines, decomposes, and recombines. Energy changes from one form to another. Matter is converted into energy in the stars, and the

What is a law in science?

How can we say that change is the basic law of the universe?

(Text pages 400–02)

(Text pages 403–07)

CONCEPT RELATIONSHIPS

Matter changes, energy changes, living things change, the environment changes, the universe changes—but within each of these changes there is order. This order enables us to predict events.

The constancy of change

stars change; the stars are in constant motion and take new positions in the universe; the universe itself is changing—but we don't know how, for sure. We suspect that changes occur in predictable order. If the pupils have successfully developed concepts, they should inevitably have acquired some confidence in the predictability of change. They should have acquired respect for the scientist who seeks orderly explanations of objects and events and for the technologist—in whatever field of applied science—who develops ways of doing the world's work, based on the predictability of change.

TEACHING SUGGESTIONS

Place on the chalkboard the sentence: *CHANGE IS THE ORDER OF THE UNIVERSE*. Ask the pupils to cite one object—just one—that will never change. Some pupils, after examining and discarding many objects, may cite atoms, molecules, electrons, or other particles of matter. Obviously all living things change, but changes in matter are a bit more subtle; they are not so readily visible. The pupils may still be seeking a solid foundation from which to kick off. Are atoms, molecules, electrons not changing? Are they not certainly—somewhere—engaging in physical, chemical, or nuclear changes? No pupil will be able to cite a single unchanging or unchangeable object. The perceptive pupil may cite that change is unchanging—thereby posing the enigma that has puzzled many persons in many fields other than science since man first began to use his brain to solve the riddle of the universe. We have been studying how changes take place during this year and *how* we use these changes.

Suggest that pupils review such questions as these:

How does matter change?

How does energy change?

How do living things get matter and energy for growth?

How do living things change?

How does environment change?

How do living things adapt to the environment?

How does man change and make things change?

How is the universe changing?

These questions focus on the conceptual schemes that recur throughout the *Concepts in Science* Series; they are charted on pages F-14-15. What one concept appears throughout our study? (Everything is in constant change.)

If everything is changing, how can we ever make any plans? How can we be so sure that the sun will come up every morning? How can we predict weather? How can we make new products and be certain they will do what we want them to do? How can we build machines or use energy and know that they will do the job we want them to do? From an examination of these and other similar questions you or your pupils may suggest, a clear understanding that events appear to take place in

Predictability of change

a particular order should result. Because of this order, we can predict with assurance. True, we can't predict when a volcano or an earthquake will make its force felt, but we can explain how they occur and cite reasons for their occurrence. Explanation of past events and predictability of future events are the fruits of our study of concepts.

As the pupils read the New View, encourage them to reconsider the conceptual schemes that are stated in italics during these four pages in their textbook to note the underlying theme of change that is present in all the conceptual schemes.

We have learned much; there is much we still need to know. We need to know more about matter in its many forms and changes. We need to know more about the many forms and changes of energy. We need to know more about how living things change and how they are interdependent with their environment. A scientist's work is never ending. Each new bit of evidence opens up new paths of investigation which may give us new knowledge and new concepts. Science has its *ends*; it seeks orderly explanations of the way the world works, but these explanations must be testable. The scientist's work is *never ending*; it is renewed adventure.

ON YOUR OWN

THE ART OF INVESTIGATION

Use of this section may be initiated at any time during the year or in connection with any of the activities in any part of the pupil's textbook or in this Teacher's Edition. The chances are that you will encourage pupils to work individually or in small groups and report their findings to the class from time to time.

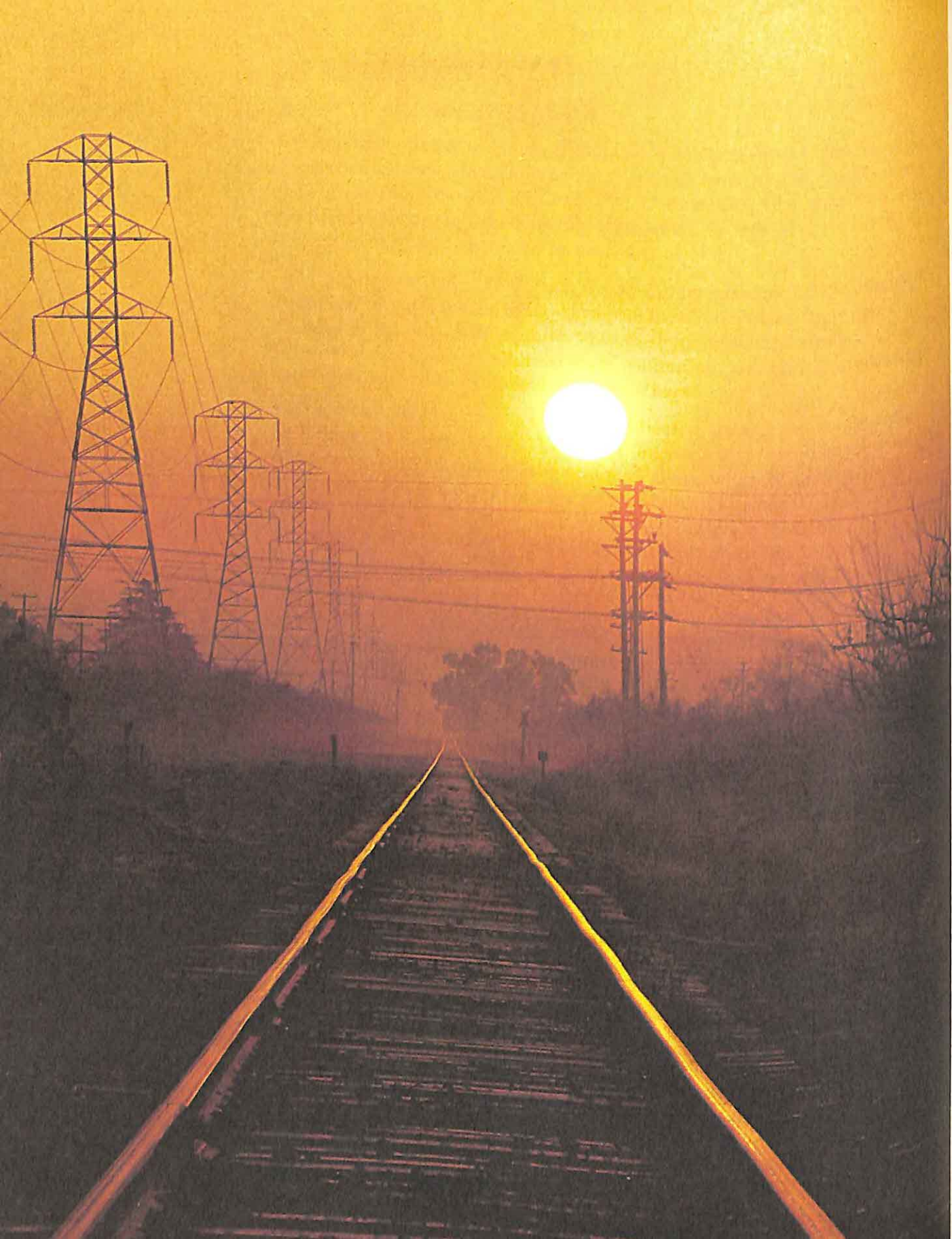
All pupils have, of course, been investigating whenever they engaged in gathering evidence to form concepts. In all activities they are continually using the skills of investigation—hypothesizing, designing experimental plans, observing, recording, computing, theorizing, analyzing, and consulting references, among many others.

The *art* of investigating is more sophisticated than mere confirmation or testing of a hypothesis. The art of investigating involves knowing *when* to use a particular skill or group of skills, when to accept the authority of a reference or an expert and when to question it, *how* to narrow the question so that the experimental design is feasible, how to recognize a new question or problem, how to analyze results, and when to go to the laboratory. *The art of investigation requires the making of decisions.*

The last half of this section proposes a few investigations and problems for which the textbook provides no answers; they are therefore truly individual and open-ended. It is well to spend a day or two orienting the pupils to the art of investigation, before they launch themselves into extensive work on a problem. Pupils who appreciate ways of analyzing a question and the need for reading, consulting, observing, experimenting, and recording (text pages 410-15) will approach their own investigation with greater intelligence and better chance of successful completion.

Pupils also should recognize that authorities do not always agree, that an investigation in the laboratory may not always turn out as expected, and that this result is not a failure but a challenge to find out what went wrong—if anything did. Perhaps the technique was wrong, perhaps the problem had not been isolated, perhaps there was another question that had to be answered first. No investigation or experiment ends in failure; something is always learned. It is just as important for the pupil, as it is for a scientist, to know when he is wrong or when his work is incomplete. A great advantage of the open-ended investigation is the cultivation of an open mind until all the evidence is in—or at least until all avenues for obtaining evidence have been tried.

TEACHER'S NOTES



UNIT NINE

STARS AND STARLIGHT

The sun is a star.

It is the center of our solar system and the principal source of heat and light for earth. It is also the source of nearly all the energy used by industrial civilizations, in the form of water power, fuels and wind. It sustains life on earth, disrupts our communications, pours deadly radiation into space, and makes our weather do tricks.

So far our knowledge of the sun has been limited because our atmosphere acts as a barrier. It completely stops most of the sun's radiant energy. In order to learn the how and why and when of the sun's phenomena we need an observatory outside the earth's atmosphere—perhaps on the moon.

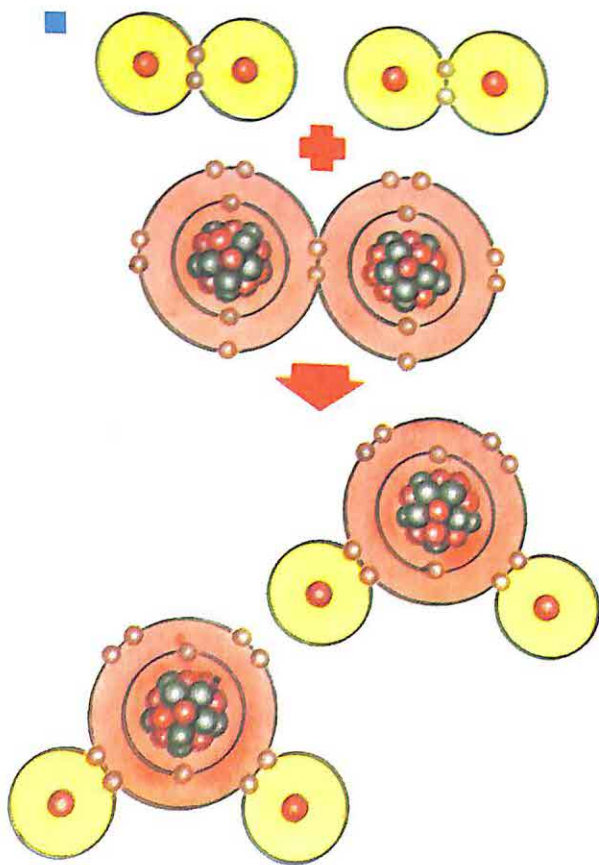
Already plans are being developed to launch an orbiting solar observatory. It may not find *all* the answers that physicists and astronomers have sought for about 350 years; but it will collect, store, and transmit data on the sun's radiation. In the process it should pick up some basic facts about the universe.

Man has only begun to gratify his curiosity about the worlds beyond this world. He is looking. He is listening. And he is stretching out long arms with electronic fingers to touch and measure the far reaches of space.

1. Energy from a Star

As we begin our study of the universe, we need to understand how stars like our sun give off so much energy.

First, let us try to combine atoms of hydrogen chemically in the classroom. We can combine atoms of hydrogen with atoms of oxygen to form molecules of water. Later, we will compare the way atoms combine chemically with the way nuclei of hydrogen atoms combine with each other. This will help you to understand what is happening in the stars. We can start with an apparatus for taking water apart, as shown in the investigation on the opposite page.

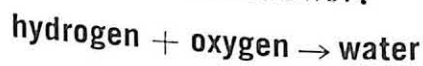


The Chemistry of Hydrogen— On Earth

Hydrogen is a gas. Only a gas could be collected by bubbling it through water. Because a gas is lighter than a liquid, the gas rises in the water. Hydrogen is also lighter than air. If hydrogen were heavier than air, would it rise in the test tube? How can you be sure hydrogen is in the test tube?

When a flame is brought near the hydrogen gas, a “pop” is heard. The popping sound is caused by the combination of the hydrogen with the oxygen in the air. This combination results in the formation of the compound water. Was there any evidence of water on the inside of the test tube?

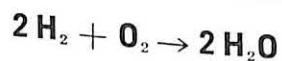
The reaction is as follows:



Or to put it in a more exact form:

A molecule of hydrogen contains two atoms of hydrogen. The symbol for a molecule of hydrogen is H_2 . Almost all the hydrogen gas on earth is made up of molecules containing two atoms of hydrogen. The oxygen gas on the earth is also found as molecules consisting of two atoms of oxygen, written O_2 .

The reaction is as follows:



Or we could say: Two molecules of hydrogen (2H_2) plus one molecule of oxygen (O_2) will react to form two molecules of water ($2\text{H}_2\text{O}$). ■

When you split the compound H_2O to form hydrogen and oxygen, how

AN INVESTIGATION into a Chemical Combination of Hydrogen

Needed: an apparatus to break up water; dry cells; dilute sulfuric acid

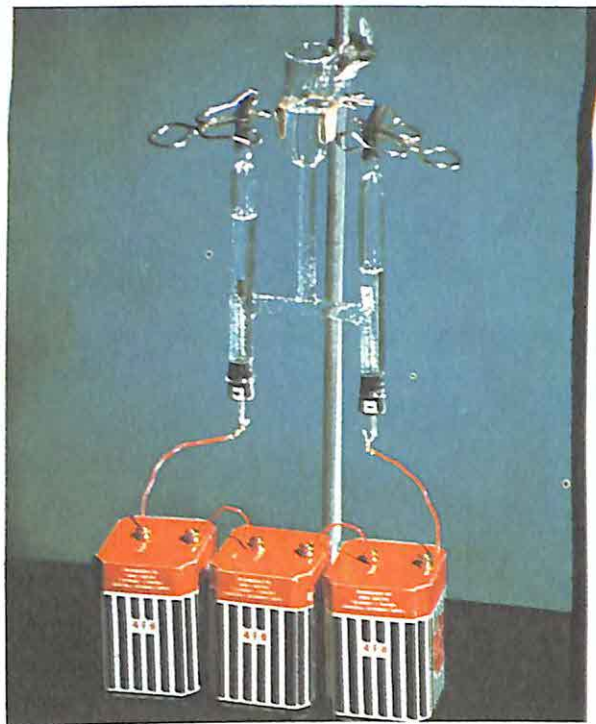
Attach the apparatus that has been set up by your teacher (called a Hoffman apparatus after its inventor), as shown in the picture. ■ The electric current is sent through the water (the formula for water is H_2O).

The electric current passing through the water splits the water molecules into hydrogen (gas collecting at the top of one tube) and oxygen (gas collecting at the top of the other). How much hydrogen will be produced as compared with the oxygen? Does the formula H_2O give you a clue?

Examine the apparatus. On which side does the hydrogen gas collect? How much hydrogen collects as compared with the amount of oxygen gas?

Now hold a dry test tube over the side containing hydrogen, as shown. ● Release the hydrogen, allowing it to rise into the inverted test tube. Why does hydrogen always rise? Keep the mouth of the tube down until a lighted splint is ready. Then hold it up as your teacher holds the lighted wood splint to the mouth of the tube.

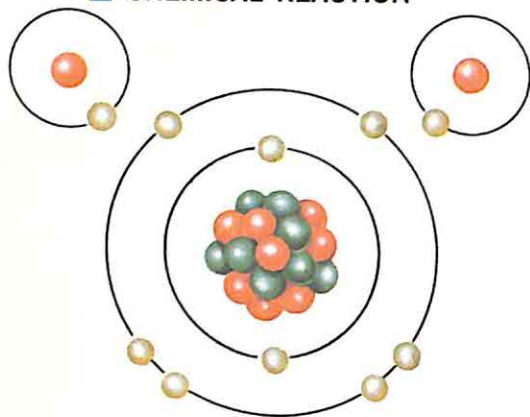
There usually is a "pop" as the hydrogen gas reacts with one of the gases in the air. Is the tube still completely dry after the "pop"? What do you notice inside the tube?



1. Which gas in the air is reacting with the hydrogen? Is it nitrogen? oxygen? carbon dioxide?
2. How can you demonstrate that the gas in the other tube is oxygen?



CHEMICAL REACTION



NUCLEAR REACTION



Hydrogen atoms can also take part in another type of reaction—a nuclear reaction. There is a difference between a chemical reaction and a **nuclear reaction**.

Look at the picture. ■ Notice that in the chemical reaction three atoms are joining to form a molecule. The particles that make up the nuclei (neutrons and protons) of the atoms are not affected by the reaction. In the nuclear reaction shown below, it appears as if the four nuclear particles themselves are going to become joined. Let us now look further into a nuclear reaction before we go 93,000,000 miles away from the earth.

A Nuclear Reaction

What happens when protons and neutrons are combined to form a nucleus or what happens when the nuclei of hydrogen atoms are *fused*?

Can it be done? Yes. In the hydrogen bomb, the nuclei of hydrogen atoms are fused. There are several different reactions by which hydrogen atoms may fuse.

As shown in the picture, it would take the nuclei of four ordinary hydrogen atoms to form the nucleus of a helium atom. ● The hydrogen nuclei are really single protons. You may wonder then why the helium nucleus has two neutrons and two protons. Two of the protons (hydrogen nuclei) react in some way to produce two neutrons during fusion. All of the particles in the helium nucleus do come from the four hydrogen nuclei.

many molecules of each were formed?

Clue: More than one molecule was split.

In these reactions the hydrogen atom is not changed. It combines chemically with oxygen to form the compound water. With an electric current, water can be split to give hydrogen and oxygen once again.

This is the basis of a **chemical reaction**. Some molecules are formed; others are broken down. Some substances can be combined and then taken apart. But the atoms that make up the molecules are not changed (see page 366).

Hydrogen nuclei can be fused with the nuclei of other elements; but the problem is to cause the nuclei of atoms to combine, or fuse, to form the nucleus of another element. When fusion takes place, there is a great burst of energy. We can therefore get energy from the fusion of atoms.

When the nucleus of an atom is *split*, a burst of energy results. This is the result of *fission* of the nucleus, as shown on pages 294-96. We can get energy from the fission of atoms, and we can also get energy from the fusion of atoms.

In the hydrogen bomb, atoms of hydrogen fuse. In the nuclear bomb, atoms of uranium split. In either case, the result is that a great amount of energy is released. How is a great amount of energy produced in the sun?

**hydrogen + hydrogen + hydrogen +
hydrogen → helium + energy**

It is definitely known that the sun has a great amount of hydrogen and helium in it. In fact, 99 percent of the sun is made up of hydrogen and helium. This information has been obtained through careful examination of the sun's light with the spectroscope, and this will be explained later in greater detail.

It appears, from a great deal of study, that the sun gives off energy from the fusion of hydrogen into helium. In a way, the sun is a great big hydrogen bomb, 93,000,000 miles away.

How do we explain the fact that when hydrogen fuses to form helium a great amount of energy is given off? The exact atomic weights of an atom of hydrogen and an atom of helium are given below. These atomic weights have been carefully measured by scientists.

hydrogen = 1.008 units of matter

helium = 4.003 units of matter

In the example of fusion given in the diagram below, four atoms of hydrogen combine to form one atom of helium. That is:



Let us do a bit of arithmetic.

1 atom of **H** = 1.008

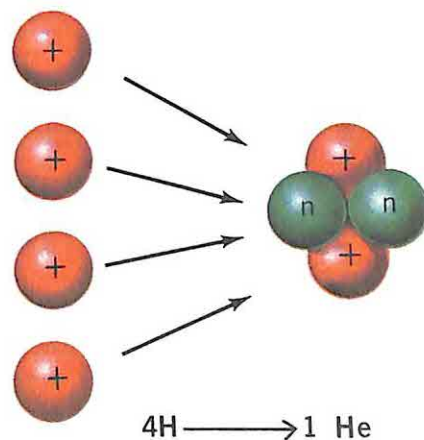
1 atom of **H** = 1.008

1 atom of **H** = 1.008

1 atom of **H** = 1.008

4 atoms of **H** = 4.032

But an atom of helium has an atomic weight of only 4.003 units of matter. This is less than the total weight of the four hydrogen atoms. Let us subtract to find how much less.



4.032

-4.003

0.029 of a unit of matter ■

What happens to the 0.029 of a unit difference?

The fate of the 0.029 of a unit of matter is this: *It is changed to energy.* In other words, little by little, some of the sun's matter is being changed to energy.

Remember that in any nuclear reaction some matter can be changed into energy. The sun's energy, then, is produced because small amounts of the sun's *matter* are constantly being changed into *energy*. In the fusion of four hydrogen atoms into one helium atom, 0.029 of a unit of matter is changed into energy. This amount of matter (or mass) is changed into light, heat, and other forms of energy. Recall, however, the main concept that although mass is changed into energy, the total amount of mass-energy remains the same.

The nuclear energy of the sun (resulting from the breaking down of matter) is tremendously important. It gives us light; it gives us heat. Without the sun the earth would soon be a frozen planet. Even the earth's atmosphere would freeze. All life would end.

The sun's heat energy and light energy are important to us for many reasons. The sun's heat energy evaporates water that later forms clouds and then comes down as rain. The sun's light energy is used by green plants to make food. Without the sun we would starve. There would be no life on earth. Even coal and oil are really chemical stores of energy from the sun that were captured by green plants long, long ago.

This star, 93,000,000 miles away, fusing its hydrogen atoms into helium, gives us the abundant supply of energy that we need to live.

How hot is the sun? This is the story of the next section.

WHAT HAPPENED TO 0.029 UNITS OF MATTER?



ATOMIC WEIGHT
OF HYDROGEN 1.008

1.008

1.008

1.008

1.008

TOTAL WEIGHT
OF HYDROGEN

4.032

ATOMIC WEIGHT
OF HELIUM

4.003



A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

- B.** Write a paragraph or two on this topic: A Nuclear Reaction on the Sun.

1. What is the difference between fission and fusion?
 - a. Which takes place in the atomic bomb?
 - b. Which takes place in the hydrogen bomb?
 - c. Which takes place on the sun?
2. Which one of the following is a chemical reaction? Which one is a nuclear reaction? In which one is matter changed to energy?
 - a. $2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}$
 - b. $4 \text{H} \rightarrow 1 \text{He}$

2. The Temperature of a Star

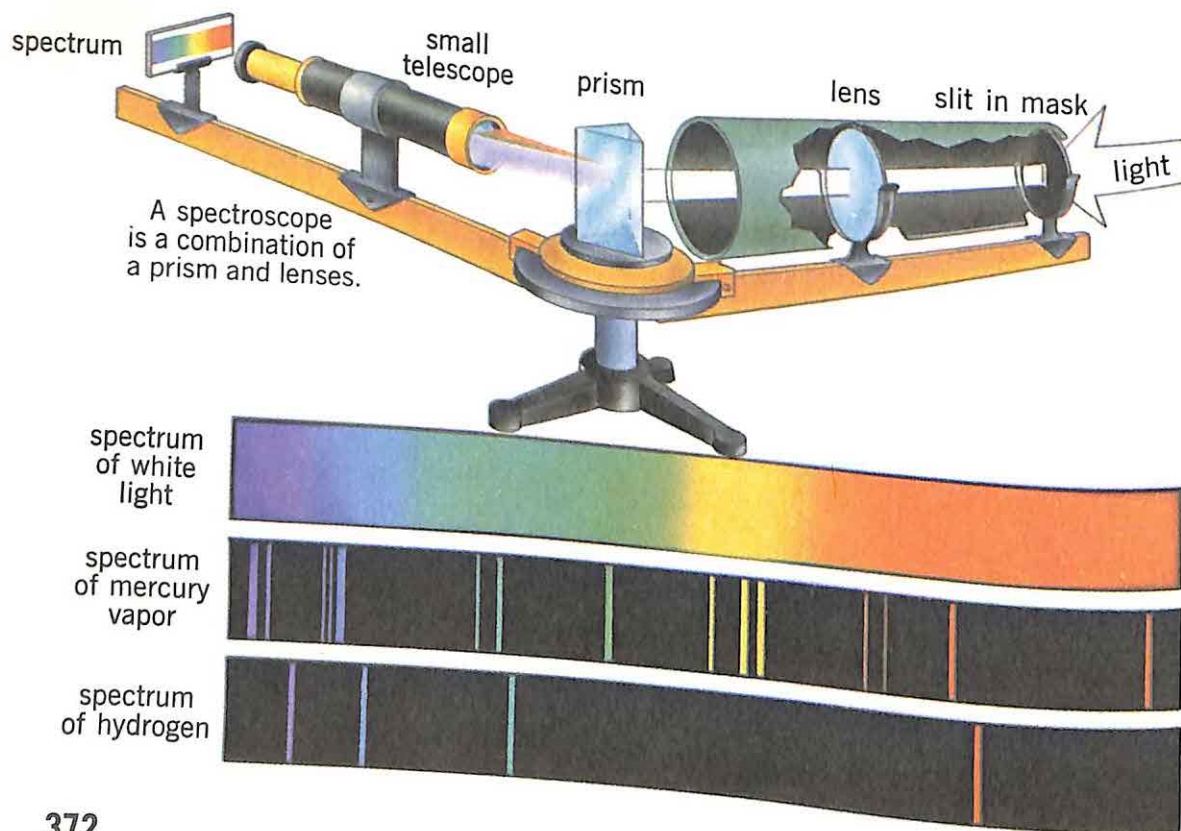
Our star, the sun, is a kind of long-lasting nuclear reactor. Hydrogen is being changed into helium, and, in the process, matter is destroyed; or is it? We could more truly say that the matter (0.029 of a unit of matter for every helium nucleus formed) is converted into energy. This energy is in the form of heat, light, and nuclear radiation.

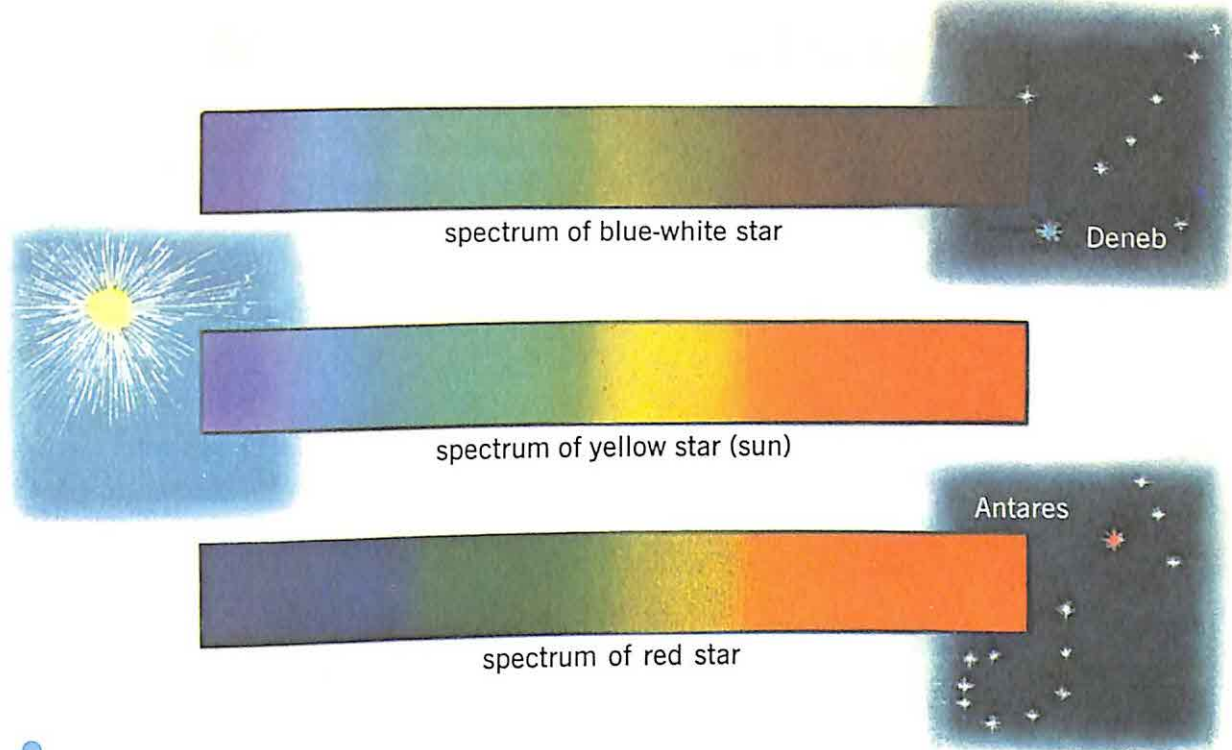
The temperature of the sun at its surface is about 11,000° F. How do scientists determine this? After all, the sun is 93,000,000 miles away, and it is not as if they were taking the temperature of boiling water.

A way of finding the temperature of stars is based on their colors. Steelworkers know that they can deter-

mine rather accurately the temperature of glowing hot steel by its color. A *white-hot* piece of steel is hotter than a *red-hot* piece. By determining the exact color of a star, astronomers can determine its temperature. They can do so by means of an instrument called a **spectroscope**.

Light from an object that scientists wish to analyze is broken up by a **prism**. If it is light from a star that the astronomers wish to analyze, they begin by "collecting" the light by means of a lens. Then they analyze the light by using a spectroscope. The light broken up by the prism shows a **spectrum** of color. The spectroscope, as the diagram shows, is really a combination of a prism and certain types of lenses. ■





Spectrum and Temperature

The spectrum from the light given off by a star also tells what kinds of elements are to be found in that star. Each element in the form of a hot gas produces a different pattern on the spectrum. The diagram shows how the spectra of two elements compare with the spectrum of sunlight. ■

The spectrum can also give a clue to the temperature of a star. In the spectrum of a blue-white star, the bluish section of the band of color is much brighter, or more intense, as shown. ● Blue-white stars are very hot. A yellow star, like our sun, has a fairly even spectrum over the whole range from violet to red. ● In the spectrum of a reddish star, the red end is brighter, or more intense. ● By analyzing the spectrum of a star,

astronomers can tell what its surface temperature is. For our purposes, there are four types of stars as far as temperature is concerned—white, yellow, red, and “dark” stars.

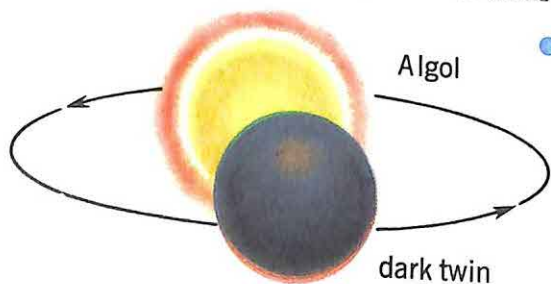
What can we learn when we analyze the spectra of different stars? Scientists have discovered that stars differ as to temperature and that a star's color is a definite clue to its temperature. For instance, the yellow-white star (for example, our sun) has a surface temperature of about $11,000^{\circ}\text{F}$. Certain blue-white stars, such as Deneb, in the constellation the Swan, have a surface temperature almost twice that of our sun. Yet the huge red star Antares (an-târ'ēz), in the constellation the Scorpion, has a surface temperature of $5,500^{\circ}\text{F}$.—only half that of our sun.



Then there are the dark stars, which give no light at all. Their discovery was very strange. Long ago, while tending their sheep, Arab shepherds noticed that a star they called Algol became dark every 2 days and 21 hours. Why did this happen? ■

Could it be that Algol's light and heat went out every 2 days and 21 hours and then came to life again? No wonder the Arabs called the star "the demon," for that is what Algol means. It took a few thousand years for man to be able to solve the mystery. Why do you think it took so long?

Algol has a twin star, a dark twin, which gives off no light. Can you figure out how the dark star could cause



Algol itself to seem to grow dark? The solution to the problem is shown in the diagram. ●

The discovery of Algol's dark companion showed that some stars—the dark ones—seem to have lost their ability to produce heat and light. Perhaps their hydrogen has been used up.

Have you another explanation?

Algol's dark twin produces little heat. Do stars with higher *temperatures* have more *heat*? What is the difference between temperature and heat? To find the difference between them, try the investigation on the opposite page.

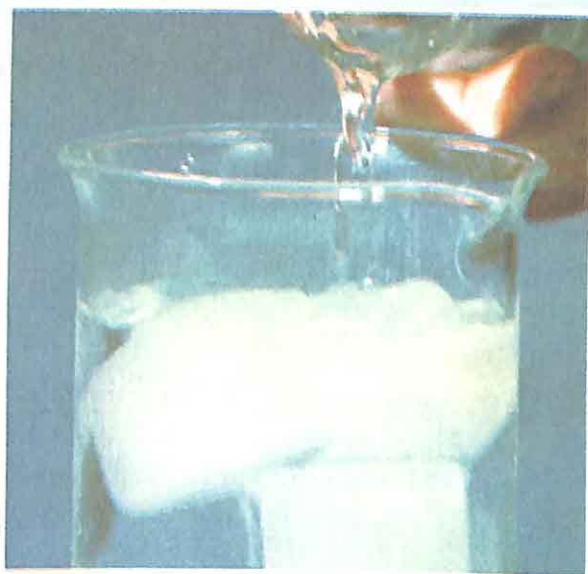
Heat and Temperature

How did you explain the results of the investigation? What is needed to melt the ice cubes? Heat? Which had more heat, the cupful of cold water or the inch of near-boiling water? Are you surprised to learn that the beaker filled with cold water has more heat in it?

The clue lies in the difference between the amount of water in the full beaker of cold water and the inch of hot water. There was a greater amount of cold water. The cold water had the greater number of molecules.

As you have learned, all molecules are in motion and have kinetic energy. The greater the number of molecules of a substance, the greater is the sum of kinetic energy of all the molecules. The sum of kinetic energy of all the molecules is equal to the heat of the substance. Thus a bathtub full of cold

AN INVESTIGATION into the Difference Between Heat and Temperature



Needed: two Pyrex flasks in which to boil water; eight ice cubes; two Pyrex beakers; a thermometer; a pair of tongs; cold water

Boil the water in one of the flasks. It will soon begin to steam. Now place four ice cubes each into two beakers.

Fill the second flask with cold water (from the faucet). Record the temperature of the water in each flask. Now pour

about an inch of boiling water into one of the beakers holding ice cubes and the cold water into the other beaker of ice cubes. ■ ●

Which ice cubes melt faster: the ones over which you poured an inch of near-boiling water or the ones over which you poured a full flask of cold water?

After several trials, compare your results with those shown below.

	Average Temperature	Average Temperature	Average Time to Melt Ice Cubes	
	Hot Water	Cold Water	in Hot Water	in Cold Water
Trial 1 (Ohio)	181° F	60° F	13 min.	7 min.
Trial 2 (Oklahoma)	187° F	58° F	12 min.	5 min.
Trial 3 (New York)	204° F	55° F	17 min.	6 min.

water has more heat in it than a glass of cold water at the same temperature. Why? The bathtub has more molecules of water moving about. The greater the amount of the substance the greater is its heat.

The cup of cold water in the investigation had more moving molecules than the inch of hot water. True, the molecules of hot water were moving faster, and a single molecule of hot water had more kinetic energy than a single molecule of cold water. Yet there were many more molecules of cold water, so the sum of kinetic energy was greater for the cold water. The cold water, therefore, had more heat. Suppose you had equal amounts of hot and cold water. Which would have more heat? Why? From your understanding of heat, what do you suppose is the answer to the problem indicated in the picture? ■



■ WHICH HAS MORE HEAT? WHY?

Now that you know the definition of heat, why not see if you can find a definition of temperature by doing some research in the library.

A star's *heat* and a star's *temperature*, therefore, give a clue to its size.

The Sizes of Stars

"Twinkle, twinkle, little star"—so goes the rhyme. But how little is little? The star you know most about is 864,000 miles in diameter. That star is our sun.

If the sun were drawn the size of a half-dollar, how large in relation to the sun would you draw the earth? The earth would be about the size of the period at the end of this sentence. How is it possible to determine the size of a star like our sun, which is 93,000,000 miles away? Perhaps you can find out by doing the same type of problem, using smaller objects and shorter distances. For example, how can you determine the size of a lamp across the room?

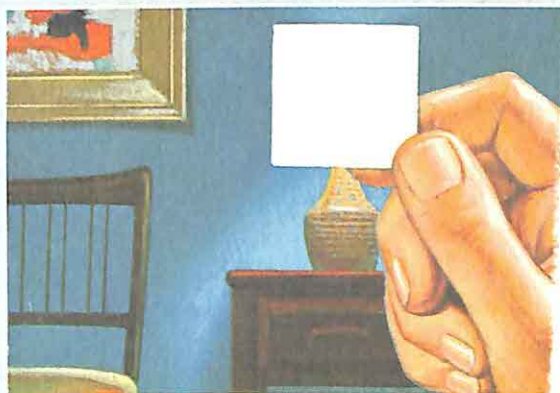
Of course, you could measure this distance with a ruler, but you cannot do that with the moon or with a star. Can you measure the size of the lamp from where you sit? One way of doing it is shown in the investigation on the opposite page.

Giants and Dwarfs

Perhaps you have not yet figured out one of the ways that astronomers can measure the sizes of certain stars.

There are very great differences in the sizes of stars. You already have a

AN INVESTIGATION into a Way of Measuring Things That Are Very Distant



Needed: an object like a lamp or a wall clock; a small card, $1'' \times 1''$

Close one eye and look at the lamp across the room, as shown in the illustration. ■ Hold the card in front of you so that it just blocks your view of the lampshade. The edge of the card should seem to touch the edges of the shade, as shown. ●

Ask a classmate to measure the distance between your eye and the card. Then ask your classmate to measure the distance from your eye to the lamp. ▲ Also, measure the width of the lampshade. Write the results of each measurement in your notebook.

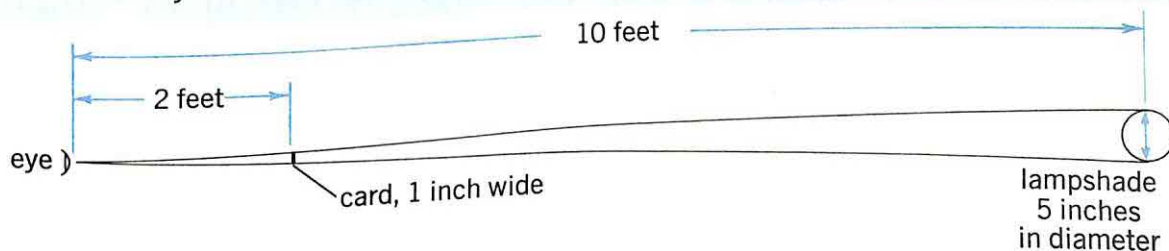
How many times greater was the distance from your eye to the lamp than to the card? *five times greater?*

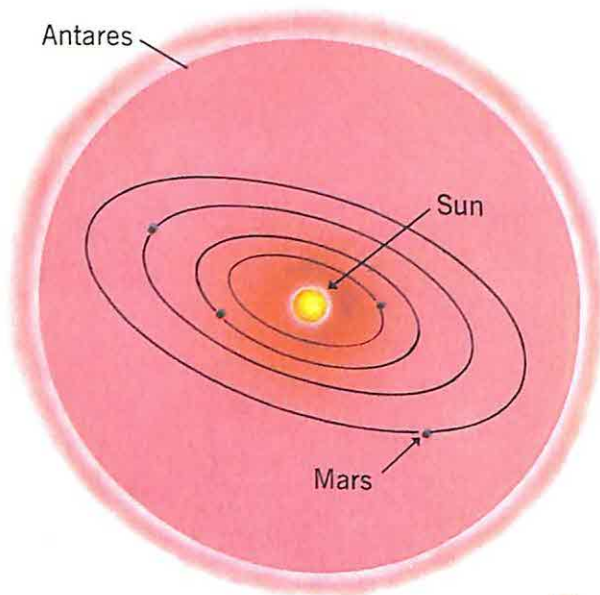
How many times wider was the lampshade than the card? *five times wider?*

How wide was the lampshade? How many times wider would you expect the shade to be than the card?

What were the results when *you* used a lampshade or a wall clock?

How can scientists use this method to measure the diameter of the moon or the sun? Astronomers have special equipment for looking at the sun. CAUTION: YOU SHOULD **NEVER** LOOK DIRECTLY AT THE SUN UNDER ANY CIRCUMSTANCES.





OBSERVATION 2:

The *entire* red star is producing more energy than the entire sun.

One explanation of these observations is that Antares, although cooler than the sun, is bigger. This would explain why the entire red star produces so much more energy than the entire sun. In fact, the diameter of Antares is about 320 times greater than the diameter of the sun. Thus, if the diameter of Antares were about the same as that shown in the picture, the sun would be about the size of the head of a nail. ■

To understand the idea of relative size in a different way, examine the orbits of the planets shown in the diagrams. The diameter of the star Antares would be greater than the diameter of the *orbit* of the planet Mars. ■

Antares is a red giant. There are a few other red giants as large or larger than Antares. Most stars, however, are medium-sized like the sun. Compared with the huge red stars, the sun is not very large.

Nevertheless, the sun is our star. We depend upon it for our light energy and, therefore, for our food, for without light energy, green plants would not be able to make sugars, starches, and other types of food. All animals depend on this food whether they feed on plants directly or feed on plant-eating animals.

Even at a distance of 93 million miles, the sun is large enough and near enough to support life on earth.

clue to the differences in the temperature of stars from pages 374–76. Some stars are red, others white, others yellow, still others dark. The temperatures of the stars can also give us a clue to their sizes.

By using the spectroscope, astronomers have found that the red star Antares has a surface temperature of about 5,500° F. Our sun has a surface temperature of 11,000° F. Thus for every square inch of surface, the yellow sun is producing more heat and light than the red Antares.

If we measure the *total heat* and light given off by Antares, however, we find that it is giving off more than 2,000 times the heat energy and light energy of the sun. How can we relate these two observations?

OBSERVATION 1:

Each square inch of the surface of Antares is giving off *less* energy than each square inch of the sun's surface.

**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Of these two, one is hotter. That one is a
 - a. white-hot piece of steel
 - b. red-hot piece of steel
2. Of these two, one has more heat. That one is a
 - a. large red star
 - b. small yellow star
 - c. small white star
3. To determine the temperature of a star, scientists use a
 - a. thermometer
 - b. spectroscope
4. The brighter portion of the spectrum of a blue-white star is the
 - a. red section
 - b. blue section
5. A yellow star (the size of our sun) as compared with a red star (the size of Antares)
 - a. has more heat
 - b. has less heat
6. A quart of water at 60°F has more heat than
 - a. a pint of water at 60°F
 - b. two quarts of water at 60°F
7. The molecules in a glass of hot water, as compared with those in a glass of cold water, are moving
 - a. faster
 - b. at about the same speed
 - c. slower

B. Write a paragraph or two on this topic: Colors of Stars.

**USING WHAT
YOU KNOW**

1. What is the source of the heat and light of some stars?
2. What is the explanation of Algol's regular appearance and disappearance?
3. What is your "educated guess" as to why certain stars are dark?

ON YOUR OWN

1. Study once again the investigation on page 377. In it you used a card $1'' \times 1''$ to blot out an object (a lampshade) on the opposite side of the room. Two measurements were necessary.

- a. distance from the eye to the card
- b. distance from the eye to the object

From these measurements you were able to get an idea of the size of the object. Can you state this relationship in a mathematical formula?

(Look back to Unit Four. There you may have tried to measure "work" by using a mathematical formula.)

2. In order to use the method in the investigation on page 377 to measure the size of an object, you must know the distance between you and the object. Thus, astronomers must know how far away a star is if they wish to measure its size.

Suppose scientists know the size of a certain star and want to know its distance from the earth. Could they use a similar method and a similar formula?

On your own, you may wish to visit the library to learn more about measuring distances in space. Guidebooks on astronomy will be of help.

3. Numbers of Stars

How many stars can you see on a clear night? Suppose you were to focus your eyes, without the aid of a telescope, on a part of the sky. What would you see? Perhaps you would see something like the part of the sky that is shown in the bottom picture. ■ Suppose, next, that you use a huge telescope to look at the same part of the sky. You might see what is in the top picture. ●

As we improve our techniques for studying the sky, we improve our

understanding of it. Even so, man studied the sky long before he invented instruments such as the huge Hale telescope located at Mount Palomar. Soon man may use the moon or space stations as observatories. From such vantage points he will learn even more about the universe and what is in it.

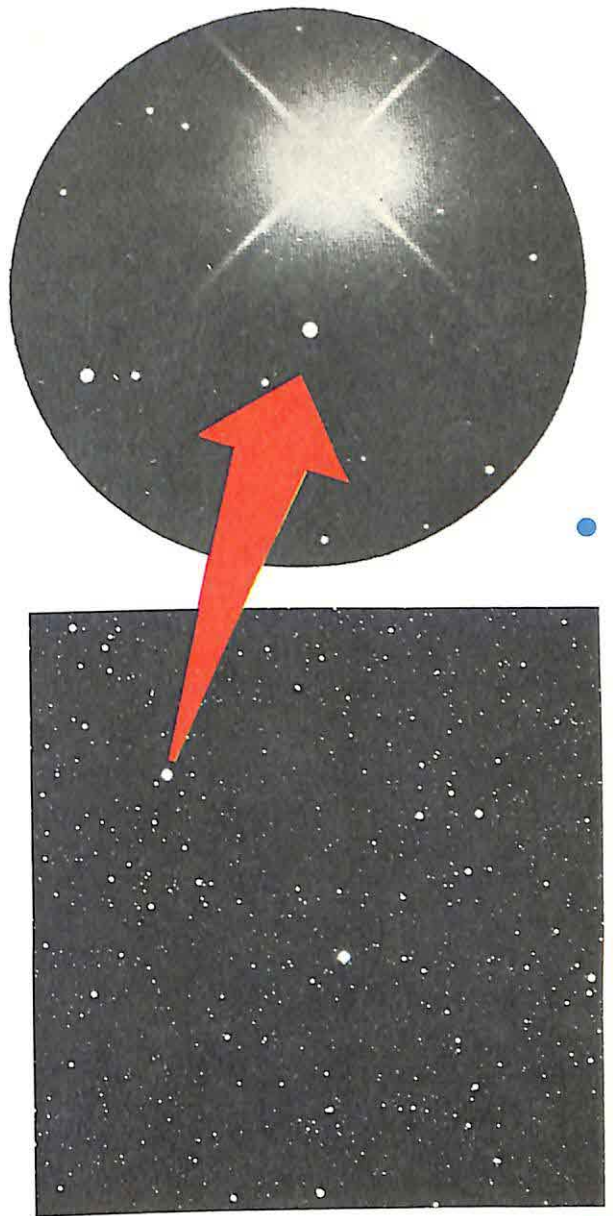
How many stars can you see on a clear night? It would be an almost impossible task to count them all. Astronomers tell us that with the unaided eye we can see as many as 2,500 stars on a very clear night. If you

used a telescope, you would be able to count many more. But, since you can see only half of the entire sky that surrounds the earth at one time, it is possible to see only about 5,000 stars, even with the aid of a telescope.

Ancient man built observatories many centuries ago. They did not have telescopes in them, but they were used to study the movements of objects in space. The remains of one at Stonehenge, England, consists of stone pillars placed in a circle. Through these, man could predict exactly where the sun and moon would rise at any time of the year. There is also evidence that this observatory was probably used to predict the eclipses of the moon.

The farther man looks into the universe, the larger it seems to be; the more stars and groups of stars he discovers. He does not yet know where, or even if, the universe ends. All he knows is that every time he develops an instrument for looking farther, he discovers that the universe is larger. Today, in addition to the giant 200-inch Hale telescope at Mount Palomar, huge radio telescopes are probing even deeper into space.

If you could make a star map of the sky section by section, however, you might be able to count all the stars. This is now being done for all the stars in our **galaxy** (gal'æk-sē), the Milky Way Galaxy. A galaxy is a large rotating mass, or system, of stars, having a common center. The Milky Way Galaxy is made up of all the stars



in the group of which our sun is a part. Astronomers say there may be as many as 100,000,000,000 (one hundred billion) stars in our galaxy. How do they arrive at that number? Is it fairly accurate? Is it just a guess? The investigation on the following pages will help you to understand one way of counting or estimating the number of stars in a galaxy.

AN INVESTIGATION into a Way of Counting Very Large Numbers

Needed: 100 brown bean seeds; 100 white bean seeds; 100 corn seeds; a large box of toothpicks—red, green, plain (your teacher will be the only one who will know the actual number of toothpicks and the number of each color)

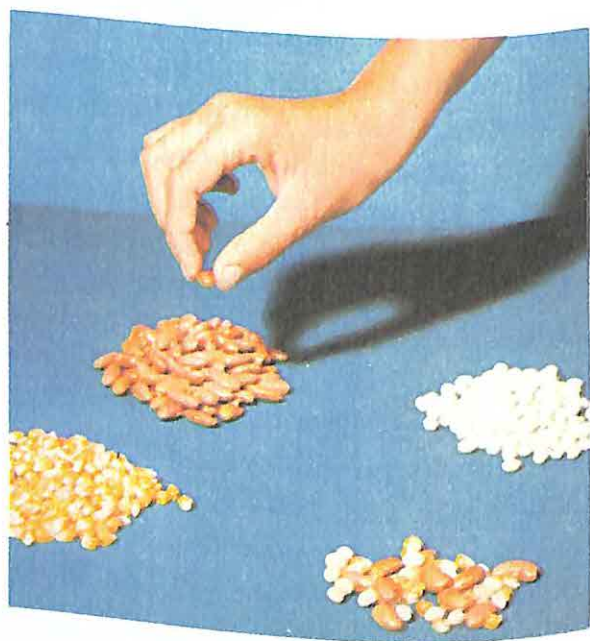
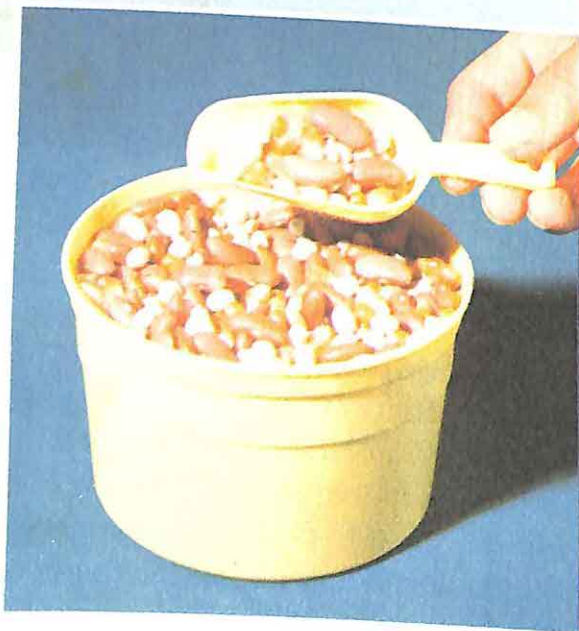
Be certain that the beans and corn are mixed thoroughly. Perhaps you might do this in a jar which you can shake again and again. Now how could you determine how many seeds of each kind are in the jar?

Try this: Scoop up some seeds. ■ Use your hand or a small cup. Each time you scoop some seeds, use the same scoop and scoop from different parts of the large jar. Count the number of white and brown beans and the

number of kernels of corn in each scoopful. ● Each scoop is a sample of the contents of the entire jar.

In two classes where this was done with the same jar of seeds, it took ten scoops to remove just half of the seeds from the jar. The results are shown on the opposite page. ▲

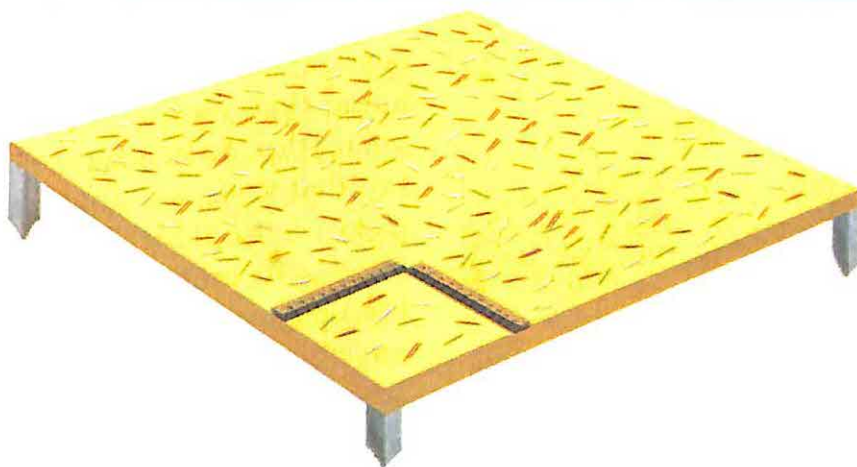
Would you conclude from this average that there are probably equal numbers of each kind of seed in the jar? Of course, you knew the answer in advance. How many seeds of each kind were in the jar? The jar was half full when you finished scooping. There must have been twice the number of those counted. You know this answer in advance, too. This is always good to know when you try out a new method of investigation.



Scoop	Number of items	Kinds		
		Brown beans	White beans	Corn
1	14	6	4	4
2	16	5	6	5
3	13	4	4	5
4	16	6	4	6
5	16	5	6	5
6	16	5	4	7
7	15	4	6	5
8	14	7	4	3
9	15	3	6	6
10	14	5	4	5
		50	48	51

This new method of counting is known as **sampling**. Now try the same investigation with the toothpicks. This time the problem is a bit more difficult. You do not know how many toothpicks are in the bunch. Also you do not know how many of each color there are.

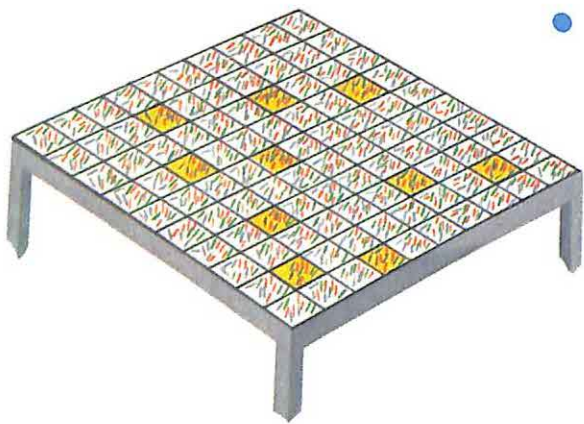
Clue: Scatter the toothpicks evenly over the top of a table where you can measure the entire area. Mark off several 1-square-foot areas. ♦ Note the total area of the table. Then calculate the total number of toothpicks and determine the accuracy of your results.





Sampling the Stars

How can the results of the investigation be applied to counting the stars of the Milky Way Galaxy? Suppose we fix our telescope on different portions of our galaxy. The telescope is attached to a camera. The observer does not watch the sky to count the stars, he photographs them. Photographs are very accurate records and



enable the observer to check carefully the parts of the sky he has photographed. Suppose he had photographed different parts of the sky—just as you (in your investigation) scooped out the beans (sampling). For example, the picture on the left shows a large section of the Milky Way Galaxy. ■ The lines show how twelve separate photographs could have been pieced together to make this picture.

Each photograph is like your scoop. It takes pictures of only certain parts of the sky. If you have samples of, for example, 100 parts of the galaxy, this is the *first* piece of information you need. What else do you need to know? You need to know the total area of the galaxy.

Recall this clue from the investigation on page 382. Scatter the toothpicks over a *known area*. It would make a great difference, would it not, whether you scattered the toothpicks over

- a. 100 square feet or ●
- b. 10 square feet.

In *a* above, if you took a sampling over several 1-square-foot areas and found that, on the average, there are ten toothpicks in each area, you might say that there are about 1,000 toothpicks on the table. In *b*, if your sampling again indicated an average of ten toothpicks per square foot, then there are about 100 toothpicks altogether. Notice the word *about*. Sampling gives you only a very good estimate of the total number. The word *about*

shows that there is some error (however slight) in the count. In any event, you must know two things about the subject of the investigation.

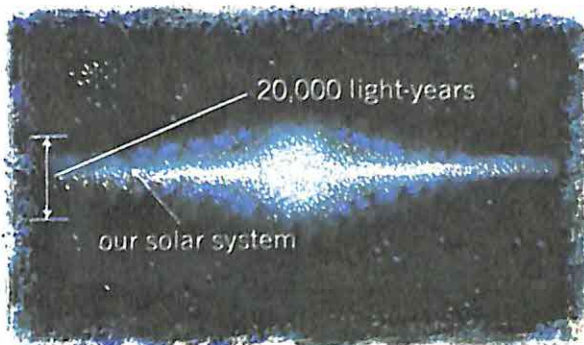
1. You must know the size of the samples.
2. You must know the size or boundaries of the entire subject you are investigating.

Our galaxy, the Milky Way, has been measured. It has not, however, been measured in the units with which you are most familiar. The distances in space are far too great to be measured with the same systems we use to measure distances on earth. The measure, or ruler, for space is the **light-year**. The light-year is the *distance* that light travels in one year at a speed of 186,000 miles per second.

In one year light travels about 6,000,000,000,000 (6 trillion) miles. The unit, 1 light-year, therefore equals about 6 trillion miles. Our galaxy has been found, by careful probing with telescope and other ways of observing, to be shaped like a pancake thickened in the center. Across, it is about 100,000 light-years in diameter.▲ Through the center, it is about 20,000 light-years.◆ Slowly it whirls about in space. What does a sampling of its stars tell us about the number of stars in the galaxy?

There are about 100 to 200 billion stars in our galaxy. The nearest star is our sun. The next nearest, Alpha Centauri, a star about the size of our sun, is about 4 light-years away. If you

MILKY WAY GALAXY



were to put a searchlight 27 miles away, you could, on a very dark night, see it as a pinpoint of light. This is about the way you see Alpha Centauri. We do not know if there is life elsewhere in space, but just suppose there was an observer on a planet in orbit around Alpha Centauri. Suppose he was using a telescope powerful enough to allow him to look at your school. Would he see it as it looks today? No. He would see it as it looked 4 years ago. Why?

**BEFORE
YOU GO ON**

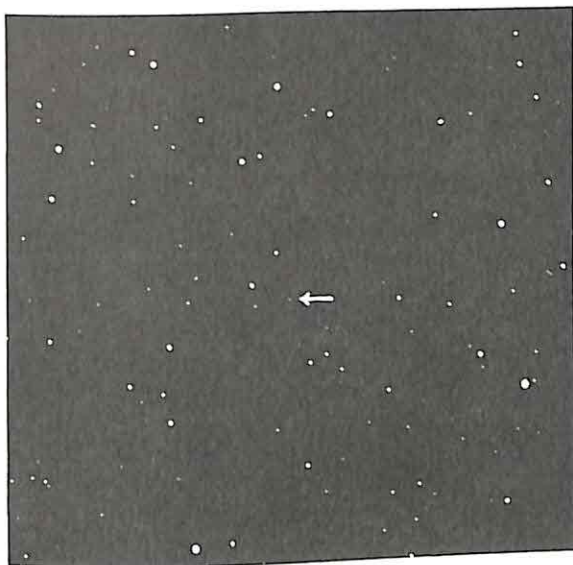
A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Our galaxy, the Milky Way Galaxy, has about
 - a. 1,000,000 stars
 - b. 100 to 200 billion stars
2. In counting stars we can use a mathematical method known as
 - a. sampling
 - b. photography
3. The unit that is used to measure distances in space is the
 - a. light-year
 - b. width of our galaxy
4. The diameter of our galaxy is about
 - a. 100 light-years
 - b. 100,000 light-years

B. Write a paragraph or two on this topic: The Light-Year.

**USING WHAT
YOU KNOW**

1. A rancher who owns a large ranch is bothered by the gopher holes on his land; sometimes horses step into the holes and injure themselves. He wants to know how many gopher holes he has on his ranch because he wants to get rid of the gophers. He has a ranch of 10,000 acres.
 - a. What method do you recommend for finding out the number of gopher holes?
 - b. How would you do it?
2. Alpha Centauri is about 4 light-years away from the earth.
 - a. How long would it take you to get to Alpha Centauri in a spaceship traveling at a speed of 1 light-year a month? (By the way, no such spaceship exists.)
 - b. Suppose that there was a planet revolving around Alpha Centauri and that organisms living on it could use telescopes. One of them is viewing a football game being played on earth on January 1, 1968. In what year would the organism see the kickoff?



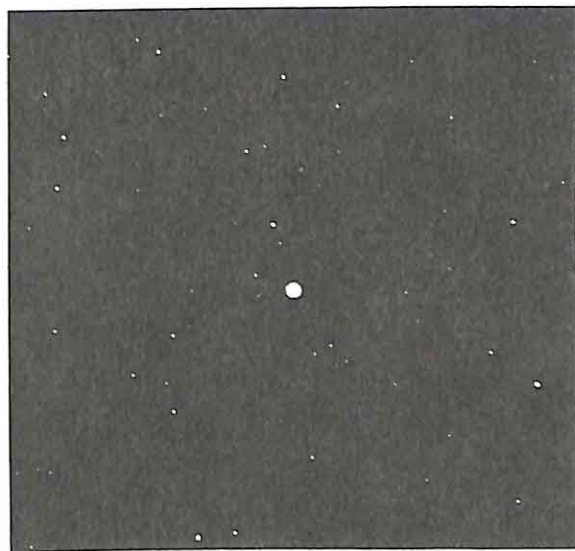
4. The History of a Star

Almost 900 years ago, in the year 1088, Chinese astronomers saw a “new” star born, or so they thought. Modern astronomers know something of the history of such “new” stars. They are really not new stars at all. How they become new stars, or, rather, how they appear to *renew* themselves and suddenly become much brighter, is an interesting story and an important one. ■ ● The story gives us a clue that indicates how the elements may have come to be.

The Meaning of a Word

Nova means “new” in Latin, so the word “nova” was the name given to a so-called “new” star. These stars are really very old but have come to life again. How is this possible?

Certain stars, like our sun, slowly use up their atoms of hydrogen in the process of fusion. This process takes

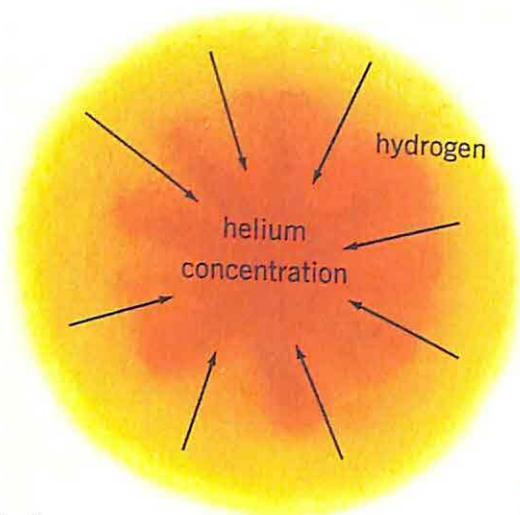


place in our sun and in many other stars as well. What can happen to a star which gets its energy from the fusion of hydrogen?

Recall that atoms of hydrogen fuse to form helium, and in so doing, some of the matter is changed into energy (page 369). Now, how long can this go on? It can go on as long as the star has enough hydrogen. If the change from hydrogen to helium continues, a time will come when no more hydrogen is left. Then what will happen? According to the best knowledge at present, this is what would happen.

Slowly, over millions upon millions of years, the hydrogen is used up. Why millions? A star is quite huge; for example, the sun has a diameter of 864,000 miles. Its volume is tremendous. 1,000,000 earth-sized globes could fit inside the sun.

As the hydrogen is used up, the helium increases. Where would you expect the helium to collect? First, a



helium atom is almost four times heavier than a hydrogen atom. Because of its heavier weight, the helium slowly gathers toward the center of the star. The lighter hydrogen remains in the outer regions of the star, as shown. ■ As the atoms of helium gather toward the center, the weight of all the matter presses the atoms of helium gas closer and closer together. What happens as atoms or molecules

of a gas are pressed closer and closer? Try the investigation on the opposite page and see for yourself.

A Star Explodes

As the hydrogen is used up, more and more helium is produced. The star becomes hotter and hotter as the pressure within it becomes greater and greater and greater. The kinetic energy of the atoms increases. The atoms of helium get even closer, bouncing against each other with greater and greater energy. The pressure builds up to such a point that the star explodes. It flares up in a brilliant, brilliant light and becomes a nova or a very huge nova, called a **supernova**. ●

The Stars—As Factories

For a long time astronomers had been wondering how the elements were formed. There are 92 natural elements on earth; oxygen, nitrogen, iron, sulfur, and uranium are examples. Scientists have been looking for a theory (an explanation) as to how the elements were formed. One fact is certain: the elements do exist.

Experimentation provided a clue. As a result of many experiments and advanced technology, scientists have been able to make several new kinds of atoms by bombarding nuclei of certain ordinary atoms with atomic bullets. Two of these new atoms are plutonium and neptunium. There are nine others, among them curium, einsteinium, and others. Some of these



AN INVESTIGATION into Compression of Gases

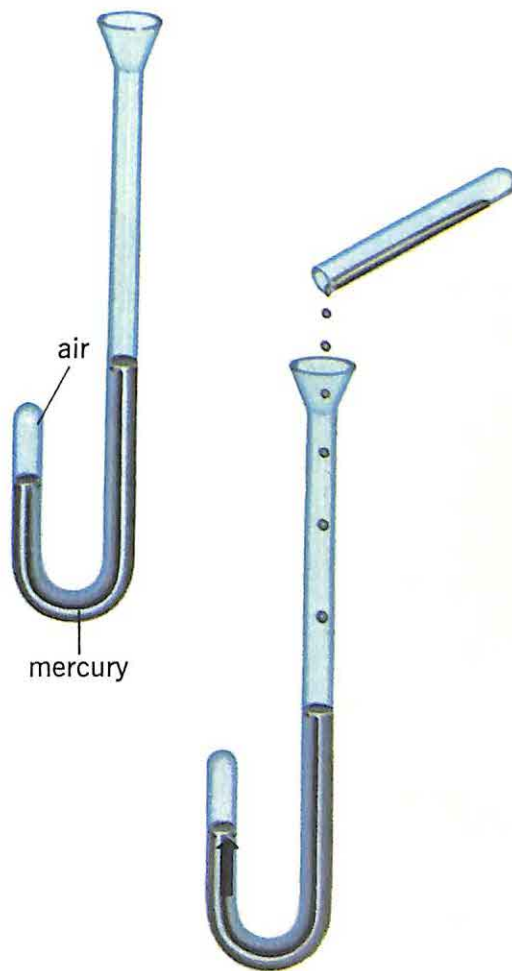
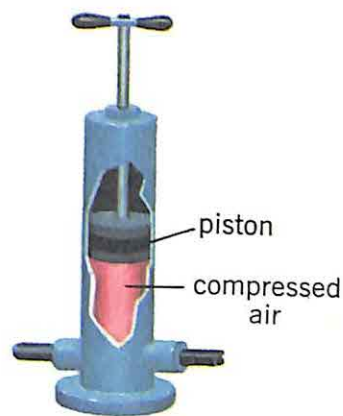
Needed: a bicycle pump; a deflated bicycle tire or a deflated basketball

Feel the bicycle pump and feel the tire. Now ask a friend to pump up the tire, and as he makes the downstroke, feel the pump below the piston. ■ Also feel the metal hose connection. What has happened? The pump below the piston has become hot. In other words, the kinetic energy of the molecules has increased.

What is your explanation of the increase in heat of the air (the gas) in that part of the pump?

The apparatus shown below the pump is called a J-tube. ● Suppose the mercury in the long part of the tube were increased in amount. The pressure on the air increases. What would you expect to happen to the temperature of the air in the J-tube as the pressure on it increases?

Additional Investigation: If a J-tube like the one shown and a small amount of mercury are available, fill the tube as shown in the diagram. ▲ What is the effect on the volume of the gas in the tip of the tube as the pressure increases? Use a ruler and measure very carefully. Which column of mercury rises more rapidly? the one on the left or on the right? How much more rapidly? Why?



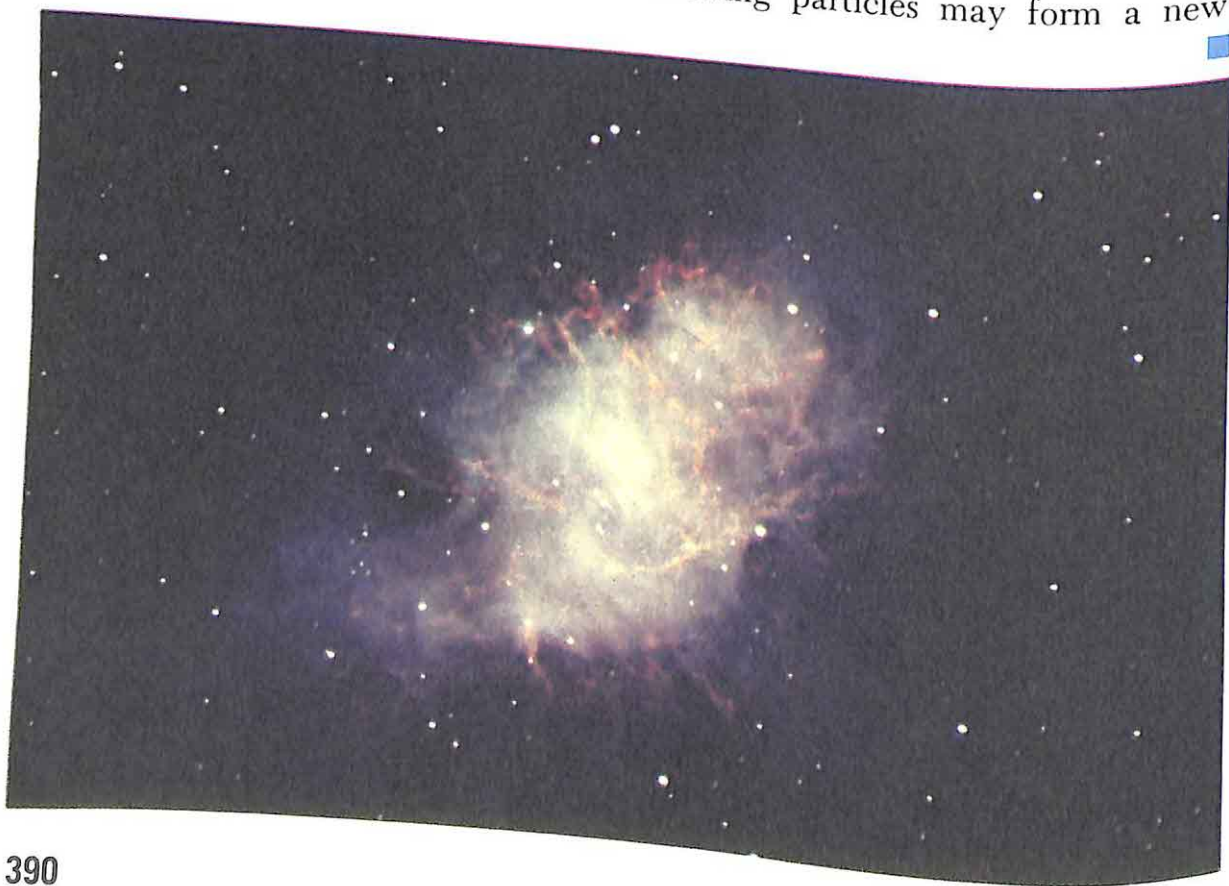
new atoms were made in atomic piles, and others were made by using the cyclotron. By bombarding certain nuclei with atomic bullets, new and larger atoms can be created.

Imagine then that a supernova flares up, spraying its surroundings with atomic particles! Neutrons, protons, electrons, and alpha particles (helium nuclei) fly apart and then come together again. As they come together, new atoms form. Over a long period of time many different kinds of atoms are formed. Some of them are the ones with which we are most familiar on earth: nitrogen, carbon, potassium, iron, and others.

As a supernova begins to cool slightly, the different particles fuse with the different atoms. Heavier and

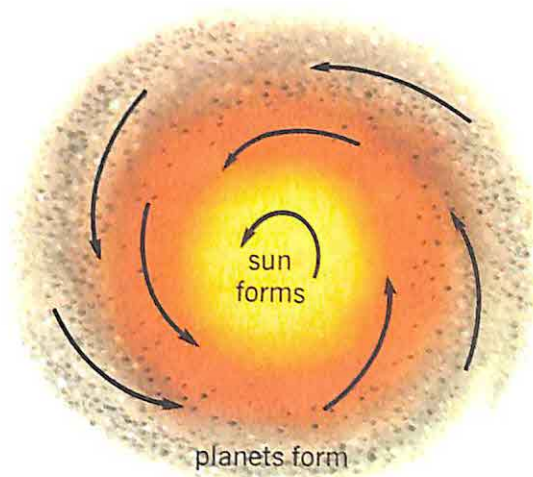
heavier atoms are formed. The supernova becomes a factory of elements. This is a theory to explain what some scientists believe happens. How else could we explain the origin of elements? Do you have a better theory? Perhaps another will be developed in the next few years.

The elements formed in the supernova are the same as those that are found on earth and in other parts of the solar system. The atoms of elements find their way into space. Sooner or later they may become a part of a cloud of whirling particles like the Crab Nebula, shown below. ■ Astronomers believe that this great mass of whirling particles was once a supernova. Sooner or later these whirling particles may form a new



star; and perhaps around this star some planets may be formed. Perhaps this is the way our solar system was born. • Perhaps this is the way the elements which make up the earth came to be part of it.

As we have said, further investigation in the years to come will give more evidence and better explanations of the evidence. Our theories may change as new evidence is introduced.



BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A nova is an
 - a. old star which becomes brighter
 - b. entirely new star
2. A star has a supply of hydrogen which is never used up. This statement is
 - a. true
 - b. false
3. A star's supply of hydrogen usually lasts
 - a. 10,000 years
 - b. millions upon millions of years
4. As atoms become compressed, their kinetic energy
 - a. increases
 - b. decreases
5. As kinetic energy increases, the temperature
 - a. increases
 - b. decreases

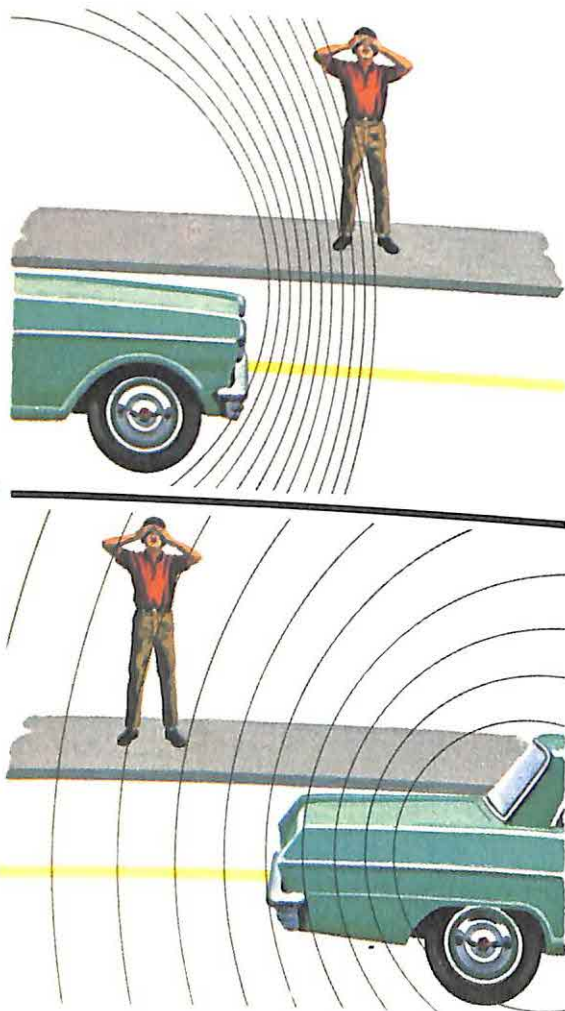
B. Write a paragraph or two on this topic: A Nova.

USING WHAT YOU KNOW

What theory is currently considered to be the best explanation for the origin of the elements?

1. What are the man-made elements? The names of some were given in the section you have read. As of now, how many are there altogether? In the library, a new reference book in chemistry should provide a complete list. They are sometimes listed as the transuranic (trans'yōō-ran'ik) elements. Why is it necessary to use a new reference book? Why would an older reference book not be satisfactory?

2. Robert Boyle discovered this law about the behavior of gases: If the temperature remains the same, the volume of a certain amount of gas varies *inversely* with the pressure. For example, if the pressure is doubled, the volume will be one-half. Can Boyle's Law be applied to the air in the J-tube (page 389)?



5. Motions of the Stars

You can find out something about the motions of the stars in an unusual way. You can get one clue by trying to find out whether an automobile is moving toward you or away from you, and you must determine whether it is moving toward or away from you *only from the sound of its horn*. Suppose you are standing on the sidewalk with your eyes closed while an automobile comes down the street with its horn blowing constantly.

Sound travels at a speed of 1,100 feet a second. As the car travels toward you, the sound waves will be crowded together. ■ When sound waves are crowded together, the sound of the horn is *pitched higher*. This is so because each second there are more sound waves coming toward you. As the automobile moves away from you, will the sound be pitched

higher or lower? ■ Why? Are the sound waves packed closer together or are they farther apart? The illustration will help you to decide.

What has this phenomenon to do with the motion of the stars?

Clues from Light

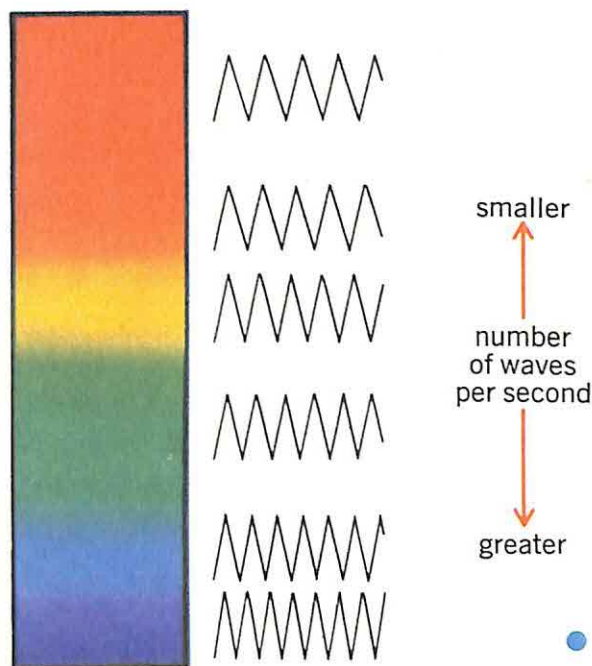
The sound of the horn gives a clue as to whether an automobile moves toward us or away from us. In much the same way, objects in space that are giving off light give a clue as to how they are moving.

If a certain object were moving toward the earth, what would happen to its light waves?

The Doppler Effect

Christian Doppler, a German scientist, wondered about certain phenomena in regard to sound. He finally described the phenomenon that is known as the **Doppler effect**.

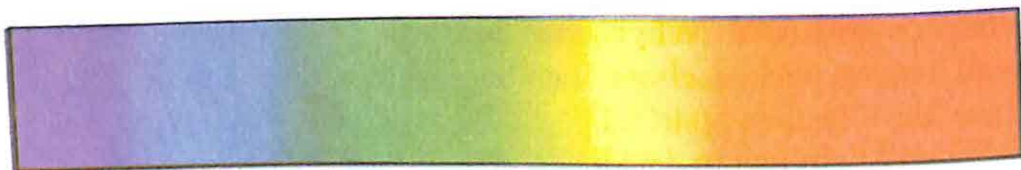
The Doppler effect is: Sound that comes from an object traveling toward you increases in **pitch**; the sound is higher. As the object travels away from you, the pitch becomes lower. The reason is that sound waves traveling in front of a moving object are pushed closer together, thereby increasing the **frequency**. Frequency is the rate at which waves (sound or light) pass a fixed point and is measured in waves per second. For instance, the string for middle C on a piano vibrates with a frequency of 256 times per second. Frequency is the rate of vibration.



How can astronomers determine whether the light from an object is traveling toward the earth or away from the earth? The clue is in the Doppler effect, and the evidence is obtained by analyzing light with a spectroscope.

Just as sound waves that come from an object moving toward you have a higher frequency, so also do waves of light. The light waves coming from an object which is moving toward the earth would be of a higher frequency. That is, a greater number of waves would reach the earth each second. Each color in the spectrum has a different frequency. ● The color having waves with the highest frequency (most crowded) is violet. Therefore, if a star were moving toward the earth, the line of its spectrum would be crowded toward the violet end. A star moving away from

normal
spectrum



red
shift



the earth would have the lines of its spectrum crowded toward the red end. Red light waves have the lowest frequency (are the least crowded) of any in the visible spectrum. This is called the Doppler shift or sometimes the "red shift."

Scientists have used the Doppler effect to study the motion of other galaxies far away from our own. They have been surprised to find that each distant galaxy has shown a shift toward the *red* in its spectrum. Does this mean that all the other galaxies are moving away from us?

Many astronomers take this as evidence that the entire universe is

spreading apart or expanding, that all star systems are moving farther and farther away from each other.

The Motions of the Stars

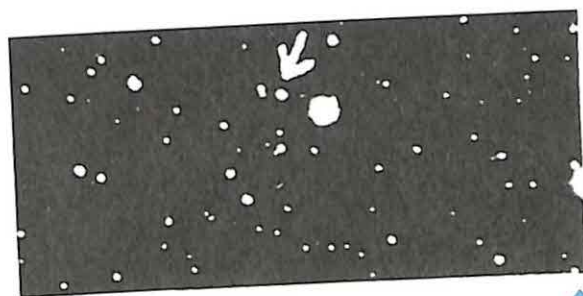
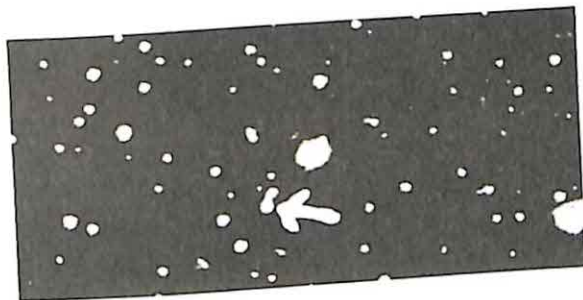
All stars are moving. The stars in our own galaxy are revolving around a center, like a giant wheel, as shown. Of course, our star, the sun, is moving, along with the other stars, around the center of the galaxy as well.

Sometimes the motion of a star can be discovered by photographs. Look at a picture of Barnard's Star (named for Edward Emerson Barnard) in our Milky Way Galaxy. Notice also the photograph of the same star taken twenty-two years later. The star has moved. It is moving even now.

Scientists can predict the motion of stars and other bodies in space, such as **comets**. For instance, it is almost certain that Halley's comet will appear again in 1985; its last appearance was in 1910. Scientists can predict its orbit and know that it appears approximately every 75 years.

Why is it that you cannot see stars and other objects in space move as you watch them? The explanation is





simple. Suppose you watch a friend walk by close in front of you. He walks quickly. If he were far away, for example, a mile, he would *seem* to move more slowly across your field of vision. Though some stars move at 50 or 60 miles a second, they *seem* to move hardly at all. The positions of the stars in the sky do not seem to have changed very much since man started to notice their movements. Barnard's Star, which moves across the sky with the greatest speed we know, has taken almost 180 years to move a distance that looks about the same as the diameter of the moon (as we see it).

All the stars move, even the North Star. It is rushing away from us at a speed of 15 miles every second. How much farther away will it be by the time you finish this sentence?

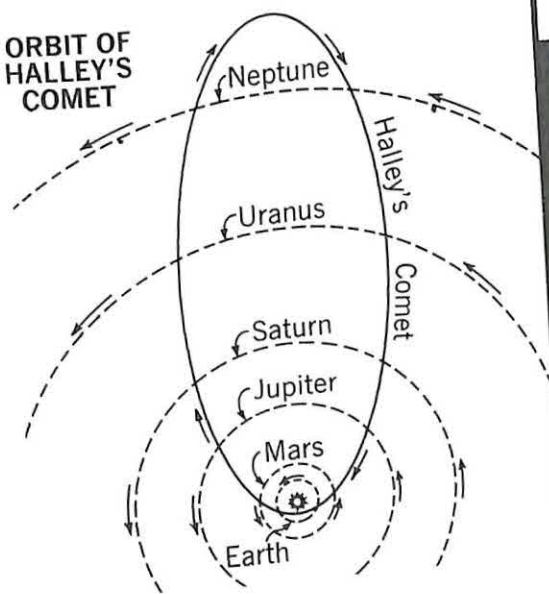
The Meaning of It All

No one quite knows what all this means to us, except that the universe is vast, with a vastness the human mind cannot seem to understand. Yet the universe is not a place where things stand still. *In our universe all is motion. In our universe everything is changing.*

All is motion.

All is change.

★ ORBIT OF HALLEY'S COMET



**BEFORE
YOU GO ON**

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. An automobile traveling toward you, horn blowing, can be distinguished from one going away from you because the sound is pitched

a. higher

b. lower

2. A star moving away from the earth would have the lines of its spectrum shifted toward the

a. red end

b. violet end

3. The Doppler shift is sometimes called the

a. red shift

b. blue shift

4. There is evidence that the universe is

a. expanding

b. getting smaller

B. Write a paragraph or two on this topic: The Uses of the Doppler Effect.

**USING WHAT
YOU KNOW**

1. In trying to solve a mysterious bank robbery, a detective had to determine where a certain car was at the time of the robbery. Witnesses near the bank agreed that the car had been blowing its horn as it sped through the streets. They all agreed that the pitch of the horn dropped suddenly and got lower.

Was the car approaching the bank? Or moving away from it?

2. The light from a distant galaxy shifts toward the red end of the spectrum. Is it moving toward our solar system? Or away?

What is the reason for your answer?

ON YOUR OWN

Who was Christian Doppler? Report on his life and work, and share your knowledge with your class.

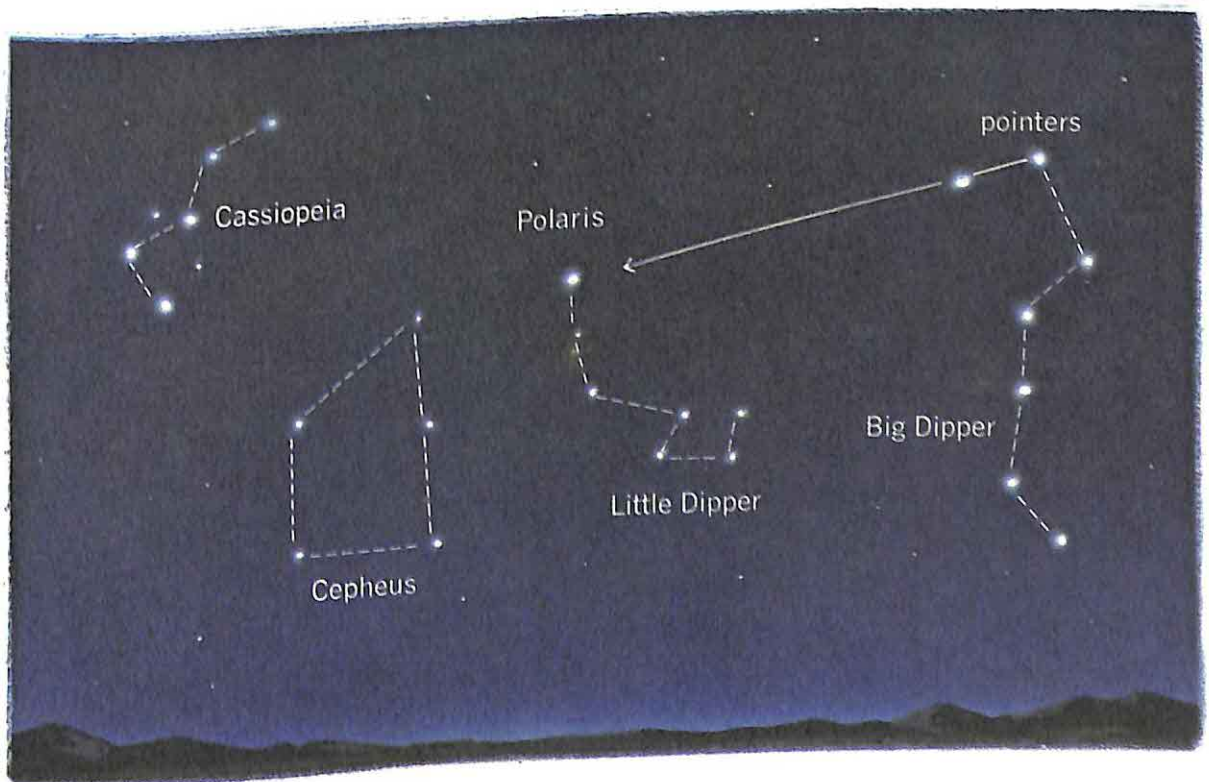
6. The Main Concept: The Changing Universe

On a dark, clear night, we look into the skies at the stars. We search out Polaris, the North Star—and there it is. ■ Ships and aircraft can be guided by the North Star. We look for other stars and there they are, just as they appear on sky charts. The moon seems always to be where it is supposed to be. All seems to stay the same; nothing seems to change.

We know differently. We know that our galaxy, the Milky Way, is whirling in the skies and that our star, the sun, is moving as well. We know our planet, earth, is moving. The evidence tells us also that all the galaxies of stars are moving away from us and

away from each other. It seems clear that everything is moving; and change is taking place everywhere. Nothing in the universe remains the same as it was a moment ago.

Should this disturb us? Not at all. The movements of the stars are not helter-skelter. The fact that scientists can predict where the stars will be tells us that their movements are regular and uniform. Their movements are orderly. Isaac Newton discovered the law that tells us how an object continues in motion and remains in orbit. Also, Newton's *Law of Gravitation* explains how objects in space attract each other. There are many other laws which man, as a scientist, has stated as he tried to find out more about the universe. These laws enable us to



understand certain events, such as the revolution of the moon around the earth. Scientific laws also help us to predict events. Thus, Gregor Mendel's *Laws of Heredity* help to explain how plants and animals inherit certain traits and how man uses them.

Understanding Newton's Laws of Universal Gravitation made it possible for us to predict what happens to a spaceship as it approaches the moon.

A scientific theory can become a scientific law if, over many years, the theory is tested by observation and experiment. If the theory continues to explain new things (such as the behavior of a spaceship approaching Mars, Saturn, or objects in space), we call it a law. Newton's Law of Universal Gravitation has been tested for about 300 years.

In the universe all is change. Stars change. We know a star to be a nuclear furnace. It may be an active furnace, a dying one, or an exploding one.

If its nuclear fuel is hydrogen, the hydrogen is fusing into helium. It is the fusion of hydrogen into helium which gives certain stars their energy—light, heat, and other forms of radiant energy. As stars change more and more of their hydrogen into helium, helium atoms become packed near the center. Finally, this packing (which causes great pressure) can no longer continue. The star explodes and becomes a nova—a “new” star.

A nova is really an old star which suddenly becomes brighter as it explodes. Novas or supernovas (giant

novas) create more changes in our universe. They seem to be factories of the elements—exploding newly formed elements out into clouds of particles. Perhaps these clouds are the beginnings of a new solar system.

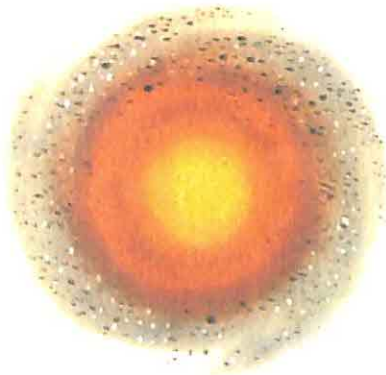
Our sun and its planets *may* have started this way, as shown in the illustration. ■ Notice how the swirling cloud of particles might have collected and changed shape to form our sun and planets. This is one way it could have happened. Much investigation must be done, however, before we will really know how our solar system started.

If you become a scientist some day, there is much for you to discover about the changing universe. If you do not become a scientist, you may still want to know what discoveries are made during your lifetime.

You must realize that you are living in a great age of investigation—investigation into the nature of the earth and of the universe.

A great deal is known but scientists realize that there is much more to be learned. After all, it has only been during the last 500 years that “modern science” had its birth. Scientists often consider that “modern science” began with Galileo, who lived from 1564 to 1642. It is only a short time that scientists have been exploring the secrets of the universe. More than half of all the scientists who ever lived are alive and at work today. It seems certain then that, in the future, much more will be discovered.

■ ONE CONCEPT OF THE WAY OUR SOLAR SYSTEM WAS FORMED



① cloud of particles spinning



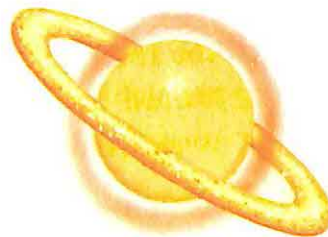
② spin increases



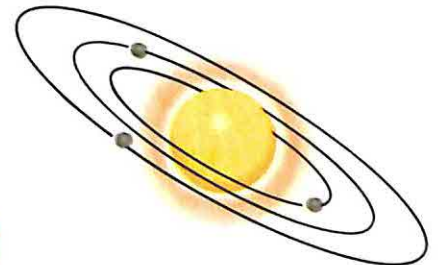
③ bulge forms



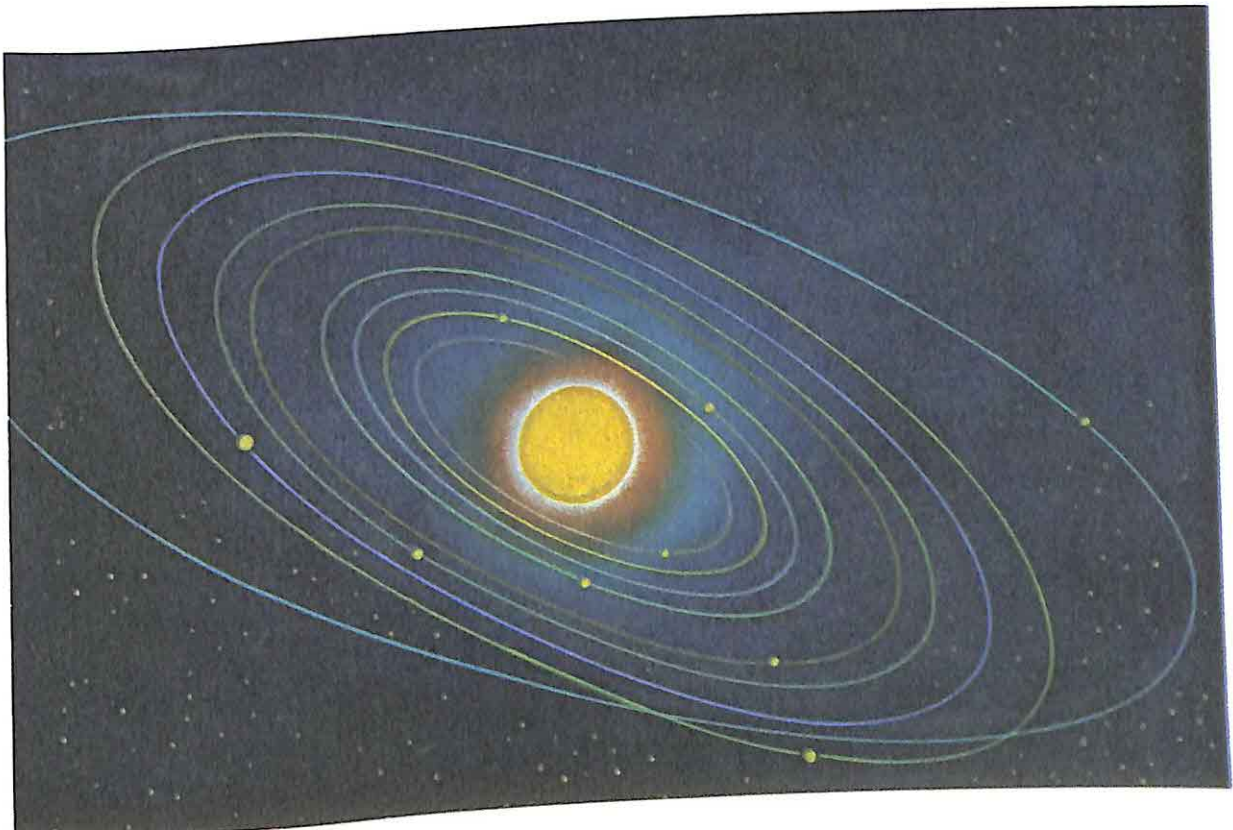
④ bulge expands



⑤ bulge separates into rings



⑥ rings separate into planets



⑦

Fixing the Main Concepts

TESTING YOURSELF

Test your understanding of the important concepts in this unit by doing these problems.

1. An object is discovered in the sky. It gives off a bright yellow light. First measurements show that it has a diameter of about 800,000 miles. The object is probably a
 - a. meteor
 - b. planet
 - c. moon
 - d. star
2. The spectrum of an object in the sky shows that it is crowded toward the red end. The object is
 - a. moving toward us
 - b. moving away from us
 - c. becoming a nova
 - d. a dark star
3. Fusion of atomic nuclei and fission of atomic nuclei are two ways of getting energy from matter. We could say that on the sun
 - a. matter is unchanged
 - b. matter is changed into energy
 - c. matter gains weight
 - d. energy is changed into matter
4. The Doppler effect could tell us all of these things except
 - a. whether an object in the sky moves toward us
 - b. whether an object in the sky moves away from us
 - c. whether an automobile is moving toward us
 - d. whether an object is undergoing fusion
5. Some scientists believe that the red shift in the spectrums of distant galaxies is evidence that the universe is
 - a. expanding
 - b. revolving
6. By determining the exact colors of a star in the light spectrum, astronomers can determine its temperature. For this purpose they use a
 - a. telescope
 - b. spectroscope
 - c. thermometer

7. When four atoms of *hydrogen fuse to form helium*, 0.029 of a unit of matter is apparently missing. It has been converted into

- a. water
- b. hydrogen
- c. energy
- d. matter

8. A bathtub full of cool water has more heat in it than a hot nail because it

- a. has a higher temperature
- b. has more molecules
- c. has fewer molecules
- d. is water

QUICK TEST

1. A gas lighter than oxygen is
 - a. carbon dioxide
 - b. hydrogen
2. One of these equations is correct. Which one is it?
 - a. $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
 - b. $2\text{H}_2 + \text{O} \rightarrow 2\text{H}_2\text{O}$
3. When hydrogen atoms fuse, we have a
 - a. chemical reaction
 - b. nuclear reaction
4. We get energy from atoms whether they undergo fission or
 - a. fusion
 - b. diffusion
5. Which one of these stars would be most likely to have a spectrum with an even range from violet to red?
 - a. a yellow star
 - b. a blue-white star
 - c. a red star
6. The light-year is a measure of
 - a. light
 - b. frequency
 - c. distance
7. The factories of elements are thought to be the
 - a. stars
 - b. comets
8. Sound waves from an object moving toward you have a
 - a. higher pitch, or higher frequency
 - b. lower pitch, or lower frequency

9. The stars do not seem to be moving because they are
a. really moving very slowly b. so far away
10. The Doppler effect is based on observations of the shifting of both light and
a. sound b. heat

**FOR YOUR
READING**

1. *The Stars for Sam*, by W. Maxwell Reed, published by Harcourt, Brace & World, New York, 1960.

This book is a full account of the stars from the time the ancients first examined them to the work of the modern astronomer. The history of stars is discussed from their "birth" to their "death."

2. *The Stars: Steppingstones into Space*, by Irving Adler, published by John Day Co., New York, 1956.

This book will help satisfy those who are especially interested in the stars.

A Concept of Change: A New View

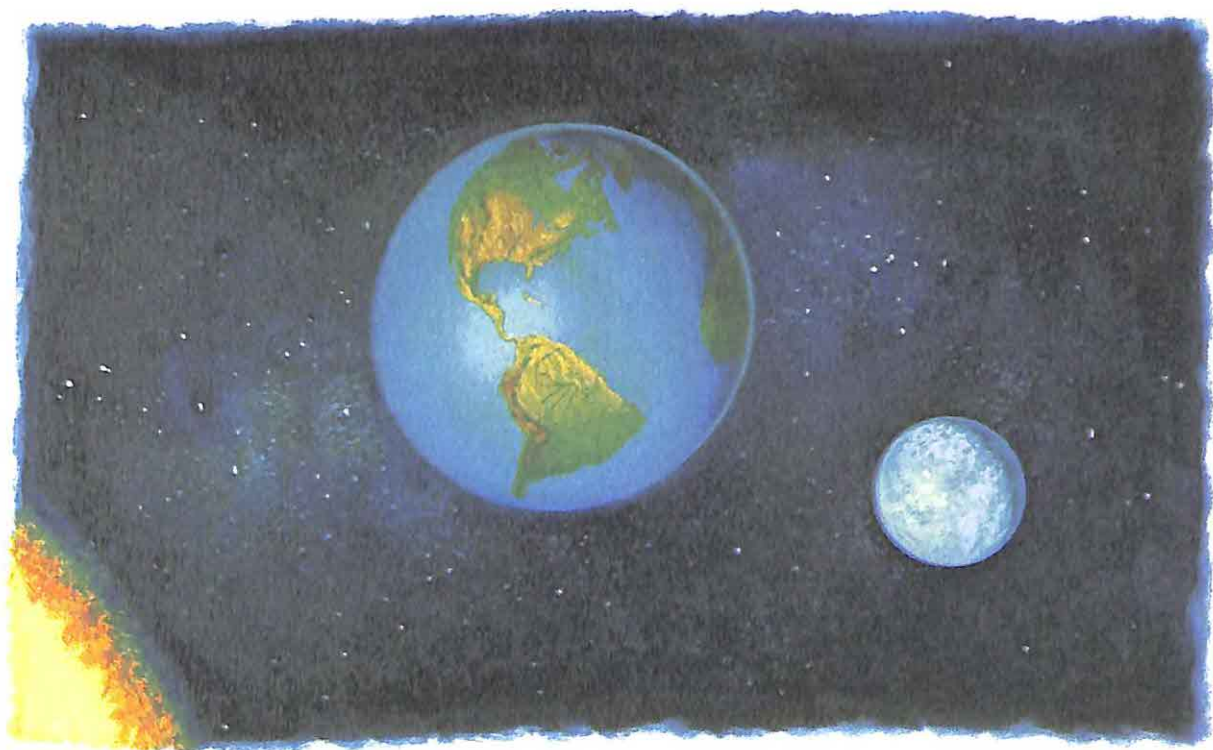
People once thought that everything in the universe remained pretty much the same; that the earth remained in the same place; that the mountains were there forever and so were the seas. ■

Now we know that "things are not always what they seem." What seems to be happening is not always what really is happening. We cannot sense the motion of the earth; yet we know that the earth and eight other planets are rotating at the same time that they are revolving at a tremendous speed around the sun.

The moon revolves around the earth; the earth revolves around the sun. The sun is only one star among the many billions of stars in our gal-

axy and all the stars in our galaxy are moving. Furthermore, there are millions of galaxies in the universe, all moving away from our own galaxy at great speed.

The universe is so vast that we cannot as yet thoroughly understand it; but we have reached the understanding that all things in the universe are in motion, and that all things change. The changes may be so quiet or so slight as to go unnoticed, or they may be as violent and dramatic as an earthquake, a volcanic eruption, a tidal wave, a landslide, or a flood. They may occur daily, monthly, seasonally, or they may extend over billions of years. Some changes are observable, but some changes can only



be reconstructed from evidence recorded in the earth itself. Man is limited only by his short period of observation.

Change in Matter and Energy

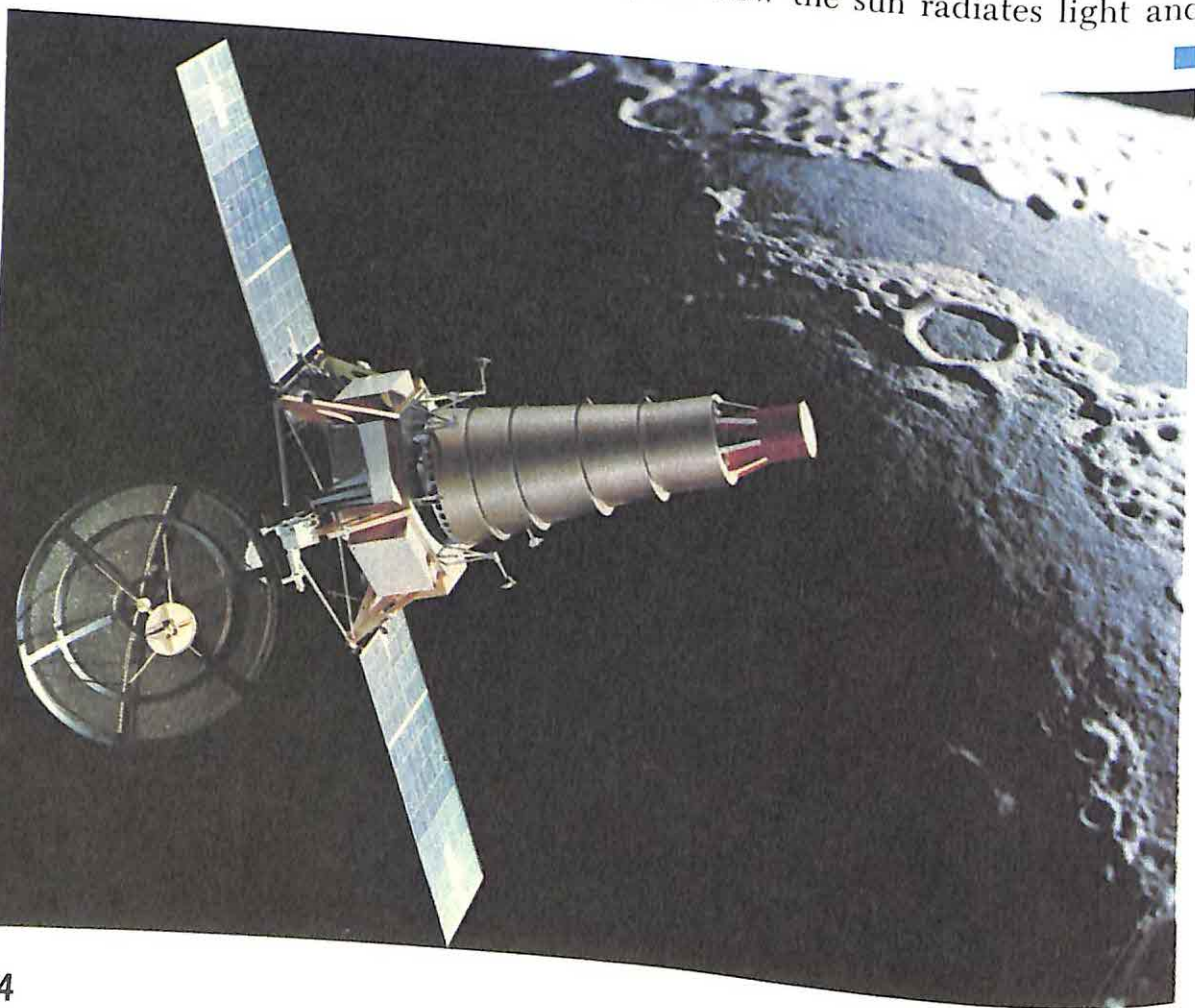
Even though our world is constantly changing, scientists know that it is not a world of disorder. As man learns and develops concepts about our world, he can predict many changes that may occur and, in some cases, control them.

For instance, scientists can predict where the moon will be at a certain time. Otherwise, they might never have been able to shoot Ranger VII

toward it or to photograph its surface, as shown in the illustration. ■ Because the movements of the earth and of the moon are precise enough to be predicted, it is even possible to think of landing men on the moon.

Man, as a scientist, does not limit his observation to only those things he can actually see. It is possible for him to explain things he cannot "see" with his eyes. He uses indirect evidence. The movement of distant galaxies, for instance, can be explained by means of the Doppler red shift.

Our understanding that matter can be changed to energy helps us to explain how the sun radiates light and



heat. The concept is restated here as: *Energy can be changed into other forms of energy. Matter can be changed into other forms of matter. Matter can be changed into energy. However, the total amount of matter and energy remains the same.*

Knowing this concept of matter and energy, it is possible to understand another great concept more easily. That concept is: *The universe is in constant change.*

As part of the universe, we too are changing. Birth, growth, maturity, old age, and death represent a life cycle of change. We change as we grow and learn. Our concepts of the world about us grow and change as we understand more science. This does not mean that what we have learned earlier is wrong. It merely means that we have learned more and, therefore, have a broader understanding. Man and, indeed, all living things are changing and have been changing ever since we began.

Living Things Change

It is now known that the growth of all living things is affected by their chromosomes. Furthermore, by determining the code in the chromosomes scientists can predict the kind of offspring that will be born, and to some extent, how it will develop. It is the DNA molecule in the chromosome which carries the hereditary code of the organism. The DNA of the garden pea carries the code (in the form of genes) that causes the plant to reproduce garden peas and not geraniums

or whales. The DNA also determines traits of the garden peas, such as color and height. A DNA code determines the traits of cattle, and dogs, and oak trees, each having its own particular code, which makes it different from other organisms.

We can cross garden peas to get certain flower colors and not others. In other words, by controlling the pollination of garden peas, we can determine the genetic code to some extent. By radiation, we can perhaps alter and study the code. It has been possible to improve our food supply by selective breeding for desirable traits.

We have learned that the molecule DNA, or the genes, can change. In other words, when the DNA molecule changes, the code is changed. New traits appear. Over millions upon millions of years, genes mutate and produce changes in organisms.

Unless we provide the organisms with the best environment in which to grow, the traits will not develop to their fullest. The illustration shows how a poor environment can hamper the development of good traits. In order to understand what environment has to do with development, an important concept must be kept in mind. The concept is: *Living things exchange matter and energy with their environment.*

It is possible to predict changes in living things, once we know something about their heredity (their genes or DNA code) and also know something about their environment.

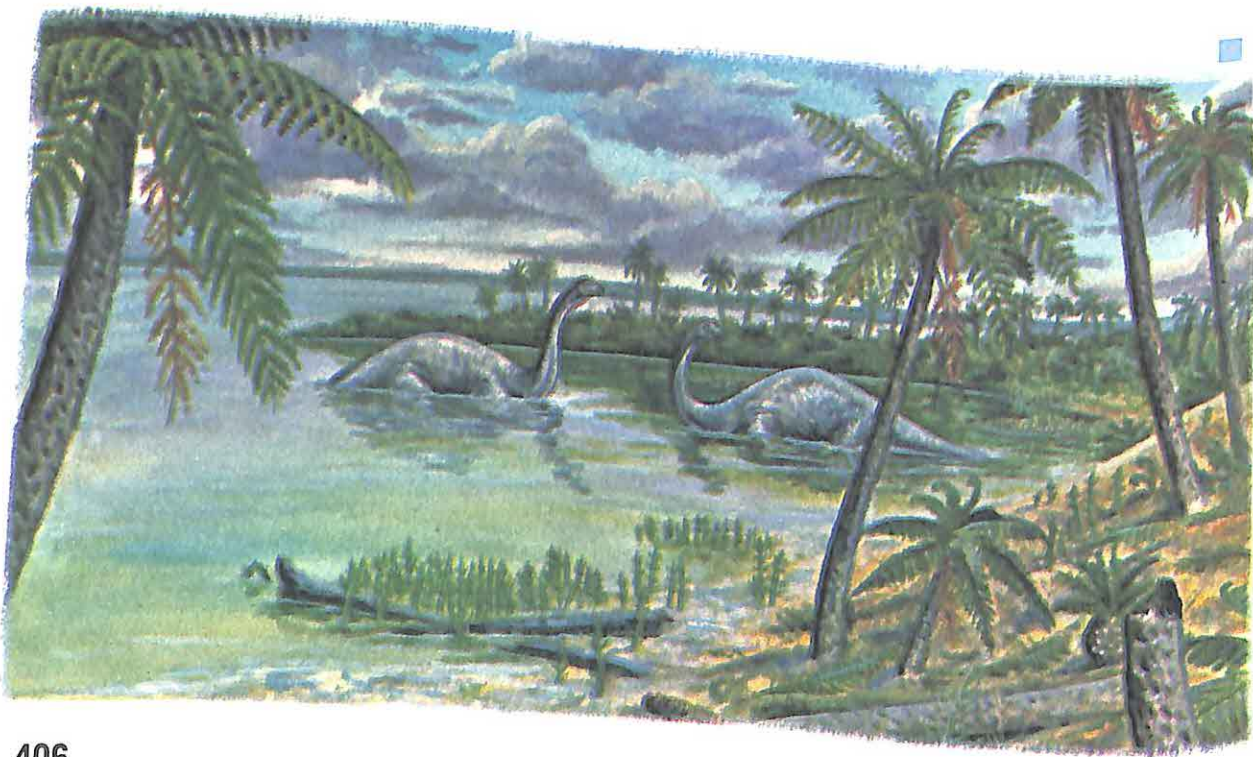
We have learned to understand how organisms develop as we have learned to understand and accept this concept: *All organisms are the product of their heredity and environment acting together.*

Over millions of years the kinds of animals and plants on the earth seem to have changed. Perhaps you have wondered why we do not see dinosaurs or the huge tree ferns that lived millions of years ago. ■ Scientists can understand this because they know that the universe and everything in it is in constant change. The organisms are in constant change as well. How have we come to understand this?

If an organism is to survive, it must be fitted to its environment. A fish, for example, is fitted to live in water, not on land. If, for instance, a pond dries out, the fishes die.

Over millions upon millions of years, the environment changed. The land environment became drier. Some of the land that is dry desert was once a moist, tropical forest inhabited by many kinds of dinosaurs. As the land became drier, those organisms that were able to adjust to a changing environment reproduced and survived. Those that were not, the dinosaurs perhaps, died out. This is one way that scientists explain why the same kinds of organisms that lived millions of years ago are no longer found.

It is therefore not only the planets, comets, and stars which change. It is not only nonliving matter and energy which change. Living things change as well. Over millions of years, only the organisms on this earth that have been best fitted to the changing environment have survived.



As the scientist explores the universe, he looks for orderly explanations of the things he sees. Whenever he sees something new, he seeks to explain it. He tests his explanations by carefully controlled investigations—often in a laboratory.

As the scientist tests the phenomena he seeks to understand and to explain, he comes to see that at least some things of the world of matter, energy, and living things can be explained and understood and predicted. As he understands the world about him, and can predict events, man can modify his environment. He can breed animals and cultivate plants to produce more food.

Developing New Concepts

The more we investigate in the manner of the scientist, the more we learn about the concepts of matter, energy, and living things. Concepts like those in the chart help us to understand the world in which we live.

Because we already understand the great concept *that the universe is in constant change*, we can also understand the concept that *organisms are in constant change*.

“Normal” processes over billions of years have changed the earth and its life to the present form. Rivers flow to the sea, cutting valleys and building deltas. They flow at different rates and carry different amounts of sediment. Rain falls, and rocks are weathered by wind, water, and changes in temperature. Waves break along the

shore, washing it away in one place and building it up in another.

The earth moves through space; conditions in space change. Forces are at work on the earth; conditions on the earth change. Living things are dependent on their environment; the environment changes. As the environment changes, living things change.

Man, like all other organisms, is interdependent with his environment. Man, as an individual, changes; man, as an organism, changes; but man makes changes of his own—in his environment, in his concepts, and in his plans for the future.

As men change, problems change. As problems change, man is forever challenged to meet the new demands of each new day, for there is still a great deal to be learned.

SUMMARY OF CONCEPTS

1. Energy can be changed into other forms of energy. Matter can be changed into other forms of matter. Matter can be changed into energy. However, the total amount of matter and energy remains the same.
2. The universe is in constant change.
3. Living things exchange matter and energy with their environment.
4. All organisms are the product of their heredity and environment acting together.
5. Organisms are in constant change.



ON YOUR OWN

THE ART OF INVESTIGATION

Not everything can be learned from books or from other people. There may come a time when you find yourself in situations where the answers are not in the book, or where there is no one around to tell you what to do, or where the answer itself may not yet be known. Sooner or later you must find out some things for yourself by investigating in the same way that the scientist investigates.

The investigations in this section are for you to do *on your own*. You will be given some help but only enough to start you off. Some of the investigations are fairly easy, while others are more difficult. As you look through them, you should find one or two—perhaps more—that will interest you. Select one that does.

Just as you learn to run by running, to write by writing, to play the piano by practice, you can also learn to investigate by investigating. You learn to solve problems by solving them. While you should seek help where you can, it is important to learn how to find out things for yourself.

Let's take an investigation apart to see how it is made up. In other words, let's *analyze* an investigation to see what we need to be careful about as we work.

1. Analyzing an Investigation

We can use an investigation that is similar to one you may have already done in Unit Three.

Background

Suppose you wanted to study bread mold under a microscope. To investigate bread mold, you would first have to grow it. You could grow some by taking a piece of white bread and exposing it to the air for a half hour. The spores of bread mold are in the air and they will fall on the bread.

Put a *few drops* of water on the bread, and place it in a closed jar. Keep the jar in a warm place. In a few days or a week you should find a growth of bread mold. ■

Suppose, however, that you want to find out whether bread mold grows better in the light or in the dark.



The Investigation

You could take two slices of bread and divide each into two equal parts. Place each part in the same kind of jar; then add ten drops of water to each piece of bread. Put two of the jars in the dark (in a closet) and two in the light.

From the evidence you might conclude that bread mold grows better in the light; but let's look into this a bit more closely. Was the temperature in the dark closet the same as it was in the light? Suppose it was not. Suppose that the temperature was higher in the light. The temperature could be higher in the light, could it not? After all, light energy can be changed to heat energy.

It is possible then that the greater growth in the *light* was *not caused by light itself* but was caused by the *higher temperature in the light*. In order, then, to do the investigation properly, it is necessary to control the temperature so that it is the same in both the *light* and in the *dark*.

What was wrong with the way you did the investigation? Scientists would say that the investigation was not well planned because not all of the variables were controlled. Temperature, light, and moisture are some of the variables in this investigation. One of the greatest mistakes made in doing an investigation is the failure to control all of the possible variables. Let's see what controlling the variables means and how important it is to control them.

Avoiding Mistakes

Suppose you wanted to find out whether moisture was necessary for the growth of bread mold. You could first dry the bread (or whatever the mold is to grow on) until it is crisp.

You could put ten drops of the water that has been boiled to kill any mold spores into one of two clean jars. ● One clean jar should be kept dry. Keep both jars on a table, side by side. Every day, change their positions to make sure that one is not any nearer a source of warmth or light than the other. The variables, temperature and light, are therefore the same for both.

It would probably be necessary to repeat this at least five times (at the beginning) to be fairly sure that your results were no accident. After all, what happens once *could* be an accident. But if it happens the *same way* in all five trials, you could be fairly certain that it happens that way most of the time. No true scientist ever stops after only one trial. Sometimes he may repeat the same procedure for as many as 100, or even 1,000, times before drawing a conclusion. He may fail many times, but he continues to try until he succeeds.

By controlling the variables, light and temperature, you made certain that moisture was the only *variable* you were observing. It was the condition of moisture which *varied*, or was different, in each of the two jars. One jar *varied* from the other by having *moisture* in it. The difference between



the conditions in the jars was reduced to *one* variable. If mold grew in the jar *without moisture* but did *not* grow in the jar *with moisture*, then you might say that bread mold did not need moisture for growth. If bread mold grew in the jar with moisture but not in the jar without moisture, then you might say bread mold did need moisture for growth.

You could come to this *tentative* conclusion, because other variables, such as light and temperature, had been controlled. The only variable which was being investigated was moisture. In doing any investigation, it is important to search out all the variables to be sure that one and only one variable is being studied at a time.

Another Pitfall

There is more to doing an investigation than simply controlling all the variables. Look at the illustration and then read on to see why. ■ Both the boy and the girl tried to find out whether moisture is needed for the growth of mold. The boy and the girl did the same investigation and controlled the variables, temperature and light. The only difference in their procedure was that the girl used a larger number of samples.

From which investigation would it be more accurate to conclude that moisture is necessary for the growth of mold? Why?

Once you have decided what you want to investigate, you must consider *two* very important things:

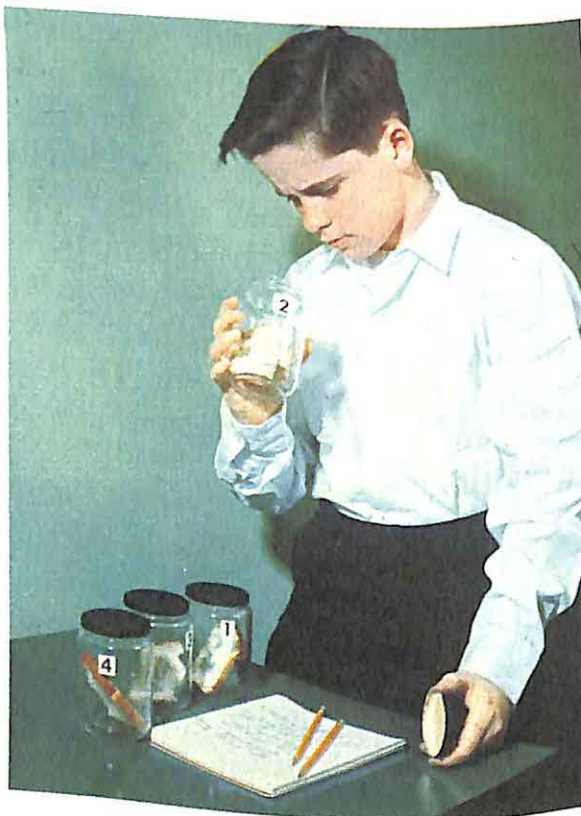
a. You must be sure that you control all the variables.

b. You must plan to repeat your investigation enough times to be confident of your results.

Now before going further, we need to look into the meaning of several important *words* and *acts*.

2. A Word About Words— And a Word About Acts

Perhaps you have noticed that the word “investigation” has been used in this book to describe almost any activity in which you “saw” the results yourself. You may be surprised that the word experiment has been avoided.



An investigation includes many things, for instance:

a. *Reading.* ● A person who investigates any subject should find out what is already known about it. Otherwise the investigator may only waste time by repeating what has already been done. To repeat what has been done is sometimes necessary, however, as you will see later.

It is always important to know the concepts upon which an investigation is based. These can often be found by reading the work of investigators who went before you. For instance, it would be peculiar if you announced that you had discovered that bacteria cause disease. Bacteria have already been discovered; and much work has been done to demonstrate that certain bacteria cause disease in man. The work of Pasteur, Koch, Salk, and many others already has been done. It is important then to find out what has already been done or discovered.

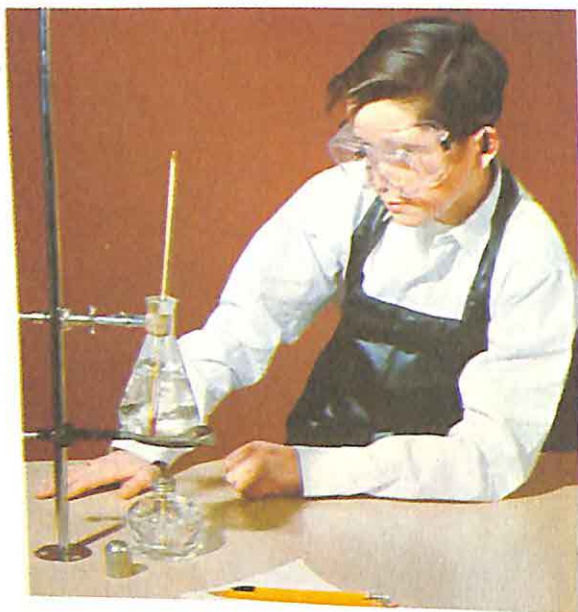
Most scientists spend a great deal of their time reading about what other scientists have done. This is often called library research. Since scientists build on each other's work, the library is important; some would say it is as important as the laboratory.

b. *Consulting.* ▲ When a book does not have the information you need, it is always helpful to talk to someone who has done work in the field you are investigating. For instance, some of the investigations which you will deal with soon are concerned with light, heat, evaporation, and con-

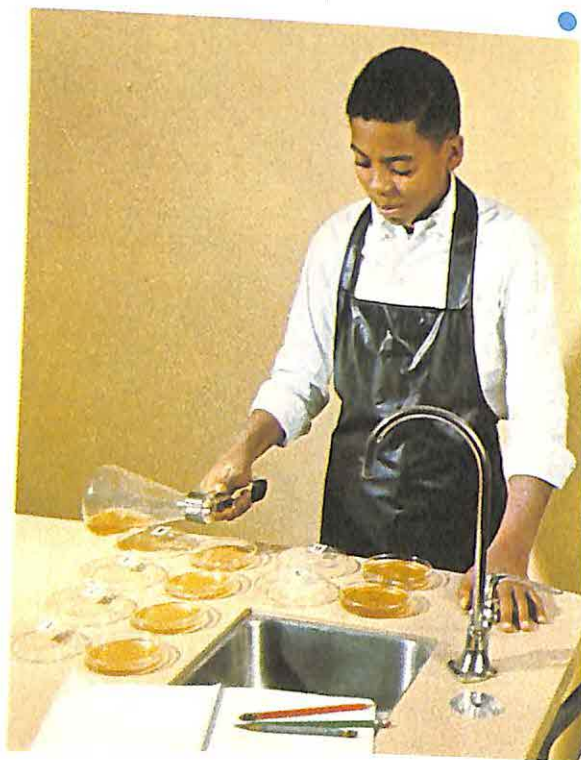


den-sation, in the study of weather. If there were a weather station in your area, you could visit it and talk with a *meteorologist* (mē'tē-ə-rol'ə-jist) (weather expert). Of course, you should first make an appointment.





Perhaps you will need to use a light meter in your investigation. If you know a photographer, it would be wise to consult him on the use of the light meter.



Consult with those who have had experience, if you can. Make an appointment before you go to see them.

c. *Observing*. Most of the investigations you have done in science required that you *observe* what was happening. By observing you use any of your senses, aided in whatever way science and technology can help. ■ Your eyes, ears, nose, and senses of touch and taste are useful, but sometimes they are not good enough. For instance, you can tell whether a substance is hot or cold by feeling it, but you might also cause great injury to yourself by doing so. (Never touch a substance to determine whether it is hot or cold. It might be burning hot, or below freezing temperature, as is dry ice.) Using a thermometer (a piece of equipment, a result of science and technology) is a better way of *observing* whether a substance is hot or cold. It is also more accurate.

In most scientific investigations it is important to know not only whether a substance has a certain *property* (heat, in this case), but also how much of it. Only by making careful measurements can you be sure that the observations you will find in this section will give you an opportunity to learn to measure accurately, or, in other words, to observe accurately.

d. *Experimenting*. If you are unable to obtain accurate information by the methods already mentioned, you may need to find out for yourself by means of an experiment. ● An experiment requires careful planning.

Later in this section, you will see that doing an experiment usually requires a good deal of preparation even before the experiment is started. You will see that *reading*, *consulting*, and *observing* are needed even before you can state the problem.

Probably the best way to learn how to do an experiment is to try to do one. You may wish to glance through those that are suggested (pages 418–22). Once you try to solve any one of these problems by *experiment*, you may discover many problems that can be solved only by experiment.

Recording: In any kind of experiment you do, it is not enough to trust your memory. You should always keep a record of your plans, your observations, and your experiments. Do this regularly and carefully in a notebook.

For example, it might be helpful to record the following things in an investigation of “weather.”

-
1. **When you did it.**
Date, Day (to check), and Time.
 2. **Kind of day.**
Weather conditions observed.
 3. **Temperature.**
 4. **What you did or observed.**
 5. **How you did it.**
 6. **Notes.** (Reminders)
-

Planning. Much time can be saved by careful planning. As well as having a good understanding of the problem, solving the problem is the real purpose of doing the experiment.

3. Investigations— On Your Own

Now you can proceed to a series of investigations in one field—**meteorology**—the study of atmospheric conditions, or weather. These investigations are intended to help you learn how to investigate, on your own. They are developed around one major concept: *Heat energy is the kinetic energy of moving molecules.* This concept is helpful in explaining the causes of different kinds of weather.

Investigation 1. How accurate are the weather predictions for your area?

The word *prediction* is an important one in science. Once a scientific concept is thoroughly understood and observations have been made to test it thoroughly, predictions can be made. The more thorough the understanding of the concept the more accurate the predictions.

There might be two parts to your investigation. First, you might record the predictions from radio, television, and newspapers, and then test them by observing what really happens. Second, you might make a prediction yourself based on reading the weather maps. In order to do this, you need to be able to understand the kind of weather map that is published in many newspapers.

One good way to do this is to select weather maps for five consecutive days. You will find a sample weather map on the following page.

Before you read the map be sure you know what each symbol on the map stands for. The important symbols are explained on the map. ■ (Where would you find out what the others mean? a dictionary? an encyclopedia? a science book?)

How accurate are the results?

Can you state them by giving the percentage of accuracy?

How accurate are your predictions in comparison with other predictions?

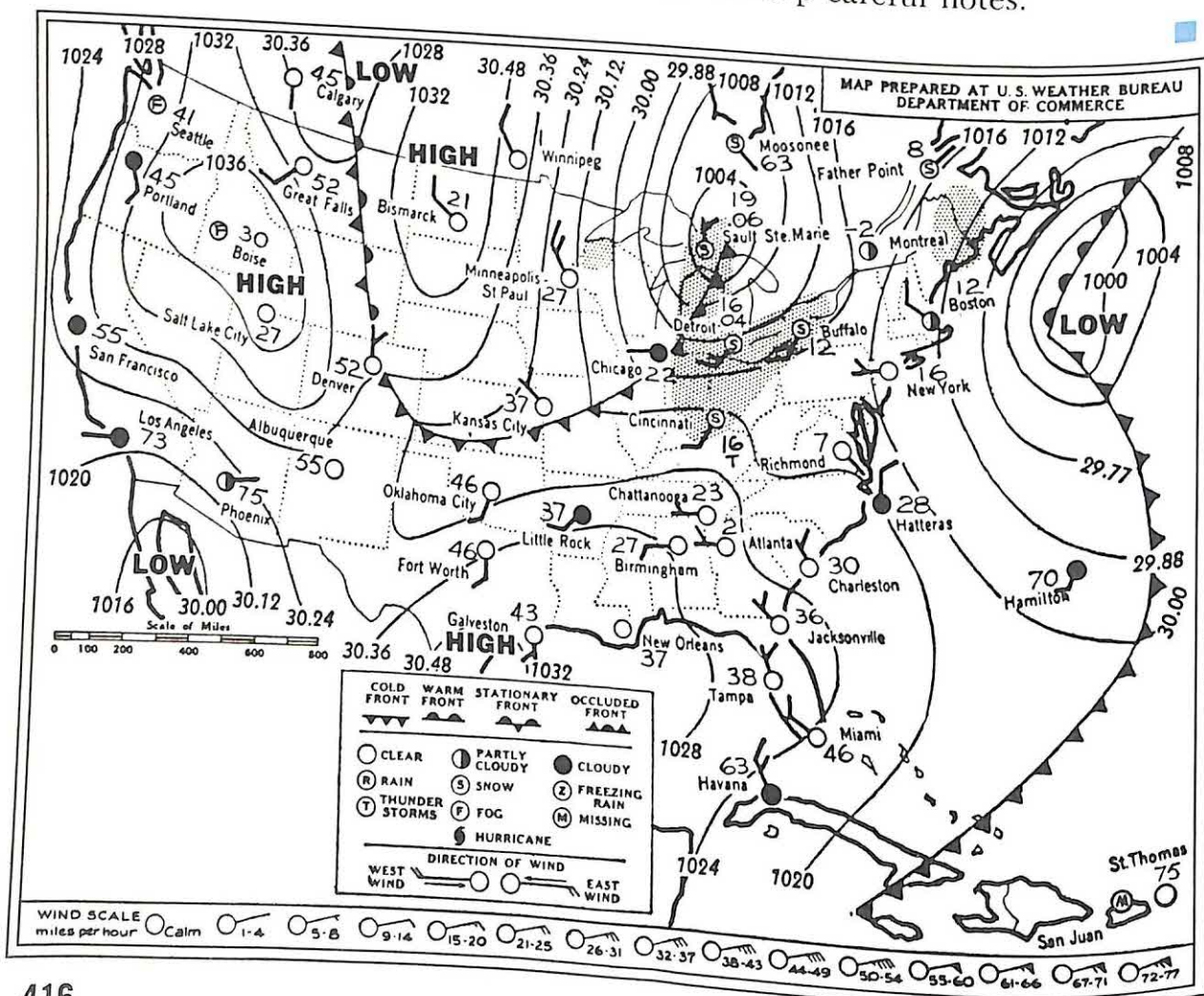
Were any of the predictions 100 percent accurate?

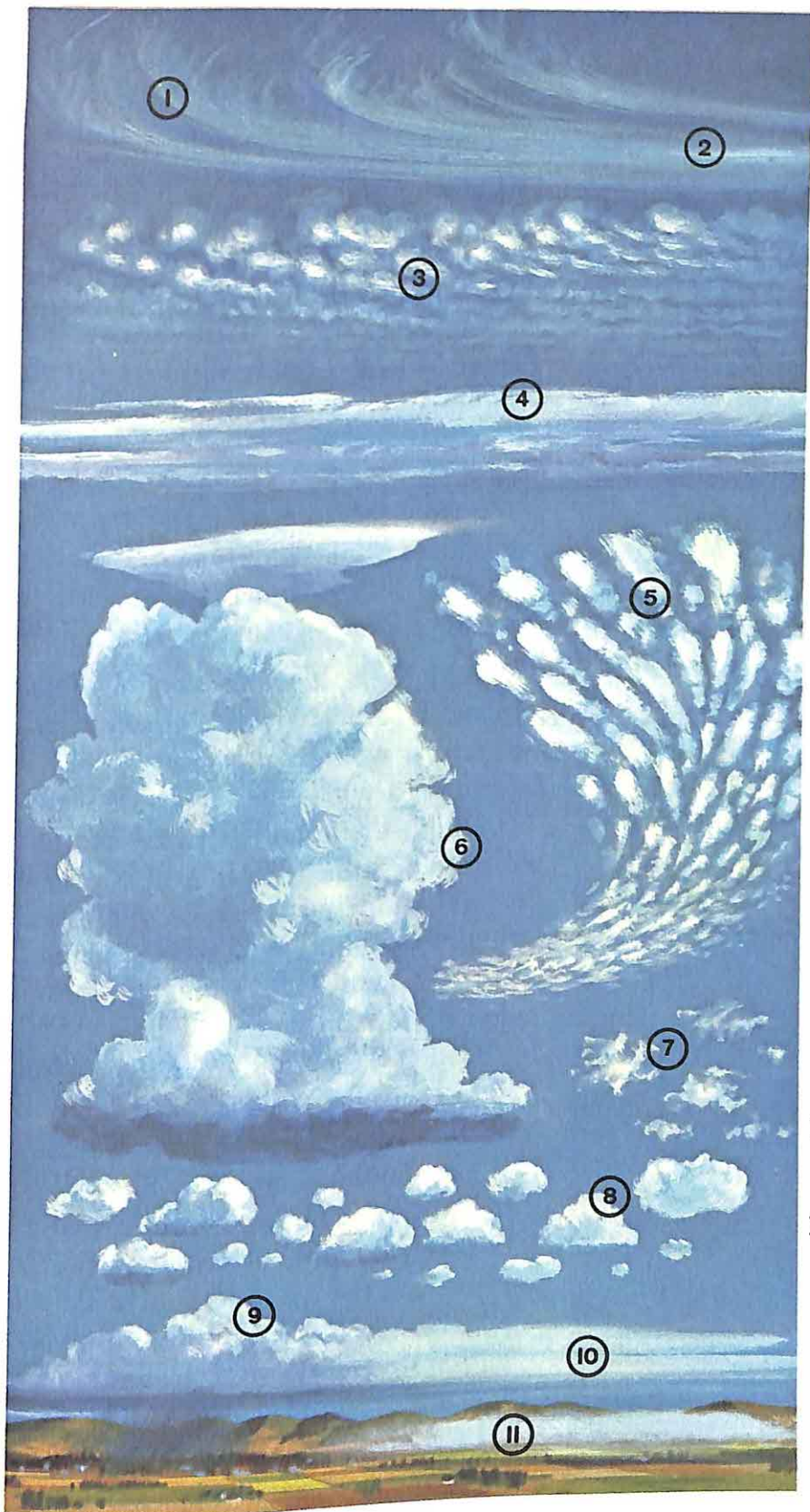
What do you think accounts for the results?

Investigation 2. Can weather be predicted by observation of clouds?

Study the chart of clouds on the facing page. ● You can learn how to identify clouds better as you become an experienced observer. Soon you will see combinations of different clouds and different cloud types.

After you have learned to identify the clouds, try to predict the relationship between the different types of clouds and the weather. For instance, does a cumulonimbus cloud (thunderhead) always produce rain? Be sure to keep careful notes.





TYPES OF CLOUDS ●

1. cirrus
"mare's-tails"
over 30,000 feet
2. cirrostratus
(like a thin veil)
causes a halo around moon
3. cirrocumulus
(like rippled sand)
over 20,000 feet
4. altostratus
(like a thick veil)
about 19,000 feet
5. altocumulus
(like a herd of sheep)
over 12,000 feet
6. cumulonimbus
"thunderhead"
lowest level about 5,000 feet
7. fractus or "scud"
(broken clouds)
8. cumulus
dome shaped heaps
4,000 feet and over
9. nimbostratus
heavy rain clouds
to about 3,000 feet
10. stratus
light rain clouds
1,800 feet
11. fog and haze
near the ground
"ceiling zero"

4. Selecting Your Own Problem for Investigation

Recall our basic concept: *Heat energy is the kinetic energy of moving molecules.* In other words, application of heat increases evaporation. On a hot day more water evaporates than on a cold day. This means that there is more water vapor to condense into clouds, perhaps. ■

Problem 1. Have you ever wondered whether water evaporates faster from oceans than from fresh water? After all, oceans have salts (sodium chloride, potassium chloride, and others) dissolved in the water.

Is there a problem, or problems, for investigation here? What is the problem? How can you investigate it? (Be sure to control all the variables.)

Problem 2. Have you noticed that oceans do not seem to freeze as often as do lakes or ponds? What is the reason for this? Is it because the oceans



are large in size, or is it because ocean water contains a great quantity of salt and other minerals?

Plan an investigation in which you control both of these variables. First design an experiment into the freezing of salt water as compared with the freezing of fresh water.

Suppose, for instance, that you were to take 1,000 milliliters (about one quart of water) of lake water, or tapwater, and were to add 40 grams of salt to it.

NOTE: 1,000 milliliters = 1 liter

1 liter = 1.1 quart

1 ounce = 28.5 grams

Would the salt water you have just mixed freeze? If it did, at what temperature would salt water freeze as compared with other types of water?

Suppose you added twice as much salt (80 grams) to a liter of water. At what temperature would it freeze then? Would it freeze sooner or not at all? You will need a good thermometer to find out.

Can you then design an experiment to test the effect that the size of a body of water has on its rate of freezing? What should your only variable be?

Now, on the basis of your investigation, try to predict whether the ice formed in the Arctic Ocean is salty or not. How could you set up an investigation to confirm your prediction?

Problem 3. Try to set up an investigation to find the real cause of evaporation. Perhaps you could obtain two

thermometers. Wrap the bulb of one thermometer in gauze that has been soaked in very warm water, and place it near the second thermometer which remains dry. ● Look at both thermometers about every 15 minutes for the next few hours. What is your hypothesis about the cause of evaporation? How would you test it?

Problem 4. Does the rate of evaporation remain the same at different temperatures?

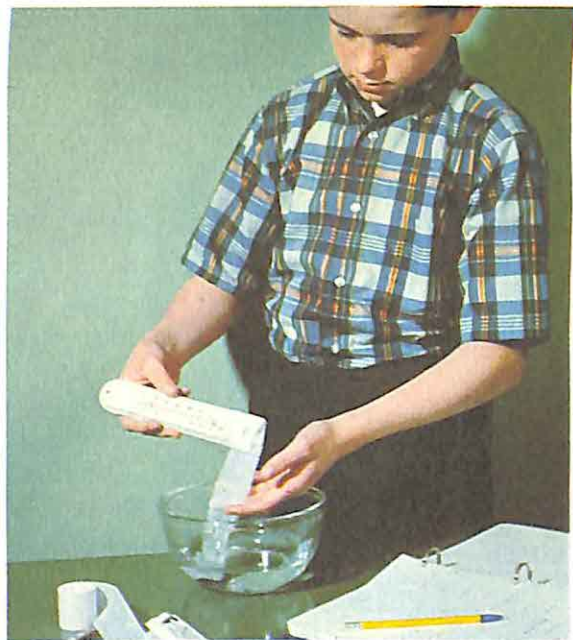
Suppose you were to put 500 milliliters of tapwater, measured carefully, in a graduated cylinder and then set the graduated cylinder into a pan of water on a hot plate, as shown. ▲ This is a kind of double boiler. The thermometer tells you the temperature of the water in the graduated cylinder. You could heat the pan to a certain temperature and, by turning the heat on and off, keep it at that level.

Does water evaporate at about the same amount for every 10-degree rise of temperature? For instance, does 5 milliliters evaporate when the temperature rises from 40°C to 50°C , and 5 milliliters evaporate again from 50°C to 60°C ?

NOTE: If the water in the pan shows signs of boiling, remove it from the heat to protect the cylinder.

Are the results different for salt water and fresh water? At what temperature does water begin to evaporate measurably?

Can you predict what will happen before you do the investigation?



Problem 5. Water vapor in the atmosphere must *condense* (kən·dens') (change to a liquid) before it can fall as rain. Meteorologists can determine the point at which water condenses; this is called the *dew point*.



Suppose you took a shiny can, taped a thermometer to the side, and filled it half way with water. Suppose you stirred and began to add ice cubes one by one to the water. At what temperature would you begin to see water condensing on the outside of the can? This would be the dew point.

Does the temperature of surrounding air have any effect on the dew point? What about the amount of moisture in the air? Would the dew point be the same on both wet and dry days?

Predict—if you can—the conditions under which the dew point would occur at a high temperature; and when it would occur at a lower temperature.

Problem 6. On page 58 you found ways to demonstrate that molecules move inside a flask or beaker of water. When water evaporates, the molecules must speed up enough to escape very rapidly out into the air.

Which color of light provides the most kinetic energy to the motion of molecules in a beaker of water? red? orange? yellow? green? blue? What effect do the different colors have on the rate of evaporation?

CLUE: Colored bulbs or colored cellophane or plastic will allow mainly that wavelength of light (color) to go through a glass.

Problem 7. What kind of insulation best retards the movement of molecules? Design an experiment to answer this question. Naturally you will

use only those materials which are available to you. You may be able to obtain and to test some of the following: rock wool, aluminum foil, fiber glass, plastic foam, cotton, cork, wool.

Problem 8. What is the effect of pressure on temperature, evaporation, and condensation? Obtain a large bottle (1-gallon size), pour a little water into the bottom, and then pump air into the bottle until the stopper flies off. (Be careful to keep your face away from the stopper.) What causes the cloud to form? See if you can use this apparatus in designing an investigation into the effect of pressure on temperature, condensation, and evaporation of water.

Problem 9. Does ice evaporate even at cold temperatures? Can you design an experiment to answer this question?

Problem 10. Try to design an investigation into how the sun causes the winds. You might use an infra-red heat lamp or a large light bulb and smoke from a smoldering rope to show the motion of air currents. The figure on the opposite page may give you a clue. ■

As you investigated each problem, did you find yourself saying something like this: "If heat speeds up evaporation, *then* the greater the amount of heat I apply, the greater should be the rate of evaporation."

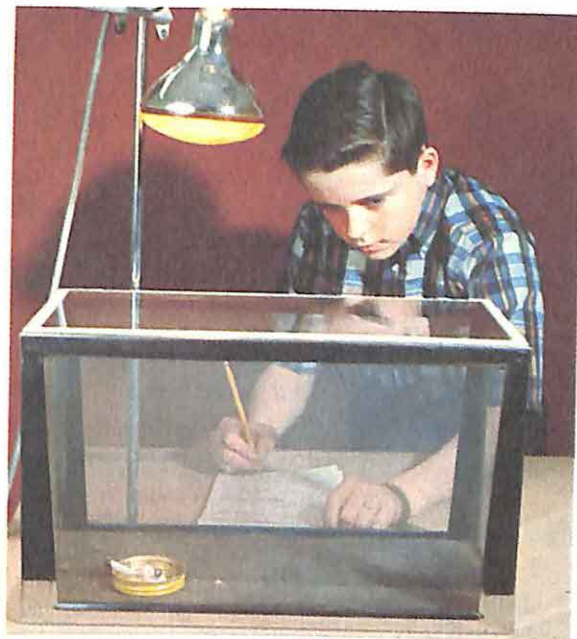
Or, suppose you asked yourself: "Does the movement of air increase the evaporation of water?" You might have answered: "*If I increase the movement of air over a pan of water, then it should increase the movement of water molecules.*"

Notice the IF—THEN type of sentence. This kind of statement is one way in which you make a kind of prediction. *If* a first condition is true, *then* the other condition, which depends on the first, may also be true. This kind of statement is called a hypothesis, or working idea.

Before you design an investigation, or an observation, or an experiment, it is useful to state a hypothesis.

Here is a hypothesis about your work in science: *If* you investigate on your own whenever you can, *then* you will learn more about the ways of the scientist. How could you investigate the truth of that statement?

Of course, "on your own" does *not* mean completely without the help of others. Your parents and teachers may help you. So will books. You will en-



counter many problems that need investigation. Your work in school will also help you to learn the ways of the scientist. As you look about this world, you will find yourself asking why, or how, or when things happen. You will find, in short, enough problems to investigate. Look around you—and use the knowledge that is available from observation, in books, and from other people.

KEY CONCEPT WORDS:

A BEGINNING VOCABULARY

FOR SCIENCE

To record what they have learned from their investigations, scientists use words that have the same meaning to every other scientist; that is, scientists try to use words accurately. You are building up a vocabulary of key concept words of science during this year. You will, of course, want to use them properly. The first time a word is used with a special meaning for scientific communication, it is in boldface type in your textbook. In this vocabulary of key concept words, a page reference is given in case you need more information or examples of the meaning than are given here. In other words, the definition given may need filling out. As you study science, the terms you use will take on a fuller meaning. A few terms you probably know from earlier work in science do not have a page reference; you should already know how to use these words in their correct meaning. The index gives other page references.

PRONUNCIATION KEY

SYMBOL	KEY WORDS
a	add, map
ā	ace, rate
ä	palm, father
e	end, pet
ē	even, tree
i	it, give
ī	ice, write

SYMBOL	KEY WORDS
o	odd, hot
ō	open, so
ô	order, jaw
oi	oil, boy
ōō	pool, food
ōō	took, full
th	thin, both

SYMBOL	KEY WORDS
u	up, done
y	yet, yearn
zh	vision, pleasure
ə	an unstressed vowel as in the words above, sicken, clarity, melon, focus

action, a force applied in one direction that is equal to the action of a force (reaction) in the opposite direction, 218

adapted, fitted by structure to carry on life activities within a given environment

alloy (al'oi), a combination of two or more elements, at least one of them a metal, which, when melted and cooled, has properties different from the original elements, 79

alpha particle, a certain type of positively charged particle given off by certain ra-

dioactive atoms; the nucleus of a helium atom, 287

antenna (an.ten'ə), a device for transmitting and receiving electromagnetic waves, 271

antibiotic (an'ti.bī.ot'ik), a substance, generally produced by a fungus plant, which, when introduced into the body, controls many bacterial infections, 121

antibody (an'ti.bod'ē), a substance made by body cells that acts against germs in the body, 126

antiseptic (an'ti-sep'tik), one kind of substance that stops growth of bacteria outside the body, 111

armature (är'mə-choör), a piece of metal or a coil of wire that moves through a magnetic field, thus causing a flow of electric current, 253

associated, related, as two stimuli given at the same time, 16

atom, a building block of elements; atoms combine to form molecules, 54

atomic number, a number assigned to identify an element; it is equal to the number of protons in the nucleus of the atom, and is an index of the properties of the atom, 296

atomic pile, a device in which atomic nuclei are made to undergo fission, 302

atomic weight, the sum of the protons and neutrons in an atom, 292

automatic (ô'tə-mat'ik) **act**, a type of behavior that does not require thought, 21

bacilli (bə-sil'i), rod-shaped bacteria, 102

bacteria (bak-tir'ē-ə), **bacterium** (*singular*), the smallest single-celled plants without chlorophyll, 100

behavior, the ways in which a living thing responds to the environment, 4; also, the ways a substance reacts to a change of any kind, 76

blend, a trait in an organism for which the characteristics from the parent genes show neither dominance nor recessiveness, 342

block and tackle, a machine consisting of pulleys fixed in two frames with a rope or chain between them and a free end for applying a force, 166

carburetor (kär'bə-rā'tər), in a gasoline engine, a chamber in which gasoline vapor is mixed with air, 208

caterpillar, *see larva*

cell, the smallest living unit of structure and function in an organism

cell membrane, the outer boundary of a living animal cell; the boundary of a living plant cell, 104

cellulose (sel'yə-lōs), the substance that makes up the walls of plant cells, 88

cell wall, the outer nonliving boundary of a plant cell, consisting of cellulose, 104

chain reaction, a process in which neutrons from the fission of one atomic nucleus cause fission of other nuclei, 302

chemical change, any change in matter that results in a change in the chemical properties of its molecules, 210

chemical reaction, a change in a substance or substances, resulting in other substances with different properties; also, any recombination of atoms in a molecule, 368

chlorophyll (klôr'ə-fil), a green substance in green plant cells that is basic to photosynthesis, 104

chromosome (krô'mə-sôm), a structure, inside a cell nucleus, containing a substance that is basic to determining the hereditary characteristics of each organism, 328. *See also DNA molecule.*

cilia (sil'ē-ə), hairlike extensions of covering cells lining the tubes to the lungs, 111; also, hairlike structures on single-celled animals by which they move about

circuit (sûr'kit), a complete path through which electricity travels, 244

classify, to group objects and events by their likenesses, 146

cocci (kok'si), bacteria that are spherical in shape, 102

cocoon, the silky covering made by a larva, from which an adult moth emerges, 85

colony (kol'ə-nē), a visible group of bacteria originating from division of a single bacterium, 101

comet (kom'it), a body in space that travels around the sun in a long narrow orbit; its head is apparently composed of many particles, and its so-called tail, of dust and other particles of matter that are most visible as it nears the sun, 394

compound, a substance consisting of two or more kinds of atoms chemically combined, 49

compound machine, a machine consisting of two or more kinds of simple machines, 177

compressor (kəm-pres'ər), a device in a jet engine that squeezes an amount of air into a smaller volume, 218

- conditioning** (kən-dish'ən-ing), a change in behavior resulting from substitution of one stimulus for another to achieve the same response, 18
- conductor** (kən-duk'tər), any substance through which an electric current can flow; also any substance through which heat can be transferred, 235
- connecting nerve cell**, a nerve cell (neuron) that transmits an impulse between one nerve cell and another, 14
- control**, that part of an experiment that includes all conditions (variables) except the condition (variable) being investigated, 11, 119
- control rod**, a device, in a reactor, which adjusts the rate of fission, 303
- corrosion** (kə-rō'zhən), the chemical combination of oxygen and a metal exposed to air and moisture, 80
- covering cells**, the outer cells of a many-celled organism or of organs inside the organism, 110
- cross**, *see* **cross-pollinate**
- cross-pollinate** (krōs'pōl'ə-nāt), to transfer pollen from the stamen of one flower to the pistil of another, 337
- culture**, a colony of bacteria grown under controlled conditions, 100
- current**, or **current electricity**, a flow of electrons through a conductor, 235
- cyclotron** (sī'klə-tron), a machine that accelerates (increases the speed of) charged nuclear particles, controls their direction, and is used to study the structure of atoms, 298
- cylinder** (sil'in-dər), a hollow tube in which a piston moves, 208
- diffusion** (di-fyōō'zhən), the spreading of one substance through another, with or without passage through a membrane
- digest** (di-jest'), to break down a complex food substance into less complex substances so that the substance can pass through a cell membrane, 107
- DNA molecule**, a large protein molecule within a chromosome; it is basic in determining the hereditary characteristics of an organism, 334. *See also* **chromosome**, **gene**.
- dominant** (dom'ə-nənt), a trait that always appears in the offspring if it is carried by a gene, or genes, in the cells, 333
- Doppler effect**, change in pitch and frequency of a wave (sound or light) as an object moves nearer or farther from the observer, 393
- effort**, a force applied to a machine, 161
- egg cell**, a specialized cell in a plant or animal which when united with a sperm cell can develop into a new organism; the female cell in reproduction, 330
- electric impulse**, a single, usually sudden, flow of electricity, 261
- electricity**, a flow of electrons
- electromagnet** (i-lek'trō-mag'nit), a magnet made of a coil of wire wound around an iron core in which the magnetic field is produced by electric current flowing through the coil, 244
- electromagnetic wave**, a form of energy that travels through space as a wave at the uniform speed of light, 270; light is one kind of electromagnetic wave (speed is about 186,000 miles per second)
- electron** (i-lek'tron), tiny negatively charged particle revolving around the nucleus of an atom, 232
- electron microscope**, a microscope that uses a beam of electrons instead of light
- element**, a substance consisting of only one kind of atom, 49
- embryo** (em'brē-ō), the living organism in a seed (before germination), in an egg (before hatching), in a mammal (before birth), 330
- energy**, the ability to do work; the ability to set matter in motion
- environment** (in-vī'rən-mənt), all the surroundings of an organism, including all matter and all forms of life with which an organism is interdependent
- enzyme** (en'zim), one of a group of substances made by cells; these substances help to break down or build up compounds in the body without generally being changed in the reaction of which they are a part, 107
- evaporate** (i-vap'ə-rāt), to change from a solid or a liquid to a gas

experience, knowledge and skills acquired from observation, investigation, and thought

experiment, an investigation carried out in a laboratory under carefully planned conditions in which known variables are carefully controlled, 118

filtration (fil-trā'shən), a method of purifying water by passing it through materials that hold back bacteria, other microorganisms, and undissolved substances, 132

fission (fish'ən), the splitting of the nucleus of an atom, 294; also, the division of a cell in reproduction

fixed pulley, a simple machine consisting of a single grooved wheel attached to a support. A rope passed around the wheel changes the direction of the force, 158

fluid, any substance that flows, as a gas or liquid, 214

force, a push or pull exerted on an object, 155

frequency (frē'kwən.sē), the rate at which wavelengths pass a fixed point in one second, 393

friction, a force, where two surfaces meet, that resists the motion of one surface across the other, 180

fuel (fyōō'əl), any substance that can burn and thus release energy, 206; also, a substance that can undergo fission or fusion and release energy

fulcrum (fōōl'krəm), the support around which a lever can turn, 156

fungi (fun'jī), **fungus** (fung'gəs) (*singular*), a group of plants without chlorophyll that obtain food from other living things, or from organic (that is, plant or animal) matter, 104

fusion (fyōō'zhən), the combining of atomic nuclei of one element, resulting in the nucleus of another, 316

galaxy (gal'ək.sē), a large group, or system, of stars which is rotating around a center, 381

galvanometer (gal'və-nom'ə-tər), an instrument for measuring a small amount of electric current, 239

gears, a simple machine consisting of toothed wheels which are meshed so that one wheel can turn another, 176

gene (jēn), a part within the DNA molecule that is basic to the development of a definable characteristic, 328

germ, any microorganism that can cause infection or disease

goal-insight theory, a theory that helps to explain learning of complex habits, 26

graft, to join the stem of one plant to the root or stem of a related plant in order to obtain more plants having a desired characteristic, 348

gram, the basic unit of weight in the metric system, 169

gravitation (grav'ə-tā'shən), a force that attracts all objects (masses) in the universe to one other; each mass tends to pull every other mass toward itself

gravity (grav'ə-tē), commonly refers to the attraction of a very large body on a small body, as the attraction of the earth or the moon for an object on its surface

habit, a learned automatic act, 21

habitat (hab'ə-tat), the environment to which an organism is adapted, 38

heat (or **heat energy**), the energy of moving molecules which, when transferred to or removed from an object, changes its temperature, 57

heredity (hə-red'ə-tē), the sum of all the traits inherited by an organism, 326

humus (hyōō'məs), decaying plant or animal matter making up a part of the soil, 102

hybrid (hī'brid), an organism that results from the mating of two organisms, each pure for a different given trait, 344

hypothesis (hī-poth'ə-sis), a possible explanation of an object or event which can form the basis for planning the design of an investigation, 119

immune, having conditions within the body unfavorable to disease-causing viruses, bacteria, or other microorganisms, 126; when these conditions exist, the body has **immunity**

inborn act, *see* reflex act

inclined (in-klind') **plane**, a machine consisting of a sloping surface placed at an angle with a flat surface, 154

infection, attack by disease-causing microorganisms, 108; such microorganisms are said to be **infectious**, 110

insight, in learning, an understanding of the means of achieving a goal, 26

instinct, a type of behavior consisting of a series of complex reflex acts, 6

insulator (in'sə-lā'tər), a substance through which heat does not travel readily, 62; also, one that stops the flow of electrons

interdependent, dependent upon one another and interacting with the environment, 39

invertebrate (in-vûr'tə-brit), an animal without a backbone, 146

isotope (ī'sə-tōp), an atom with the same atomic number as another atom but with a different atomic weight, 302

kinetic (ki-net'ik) **energy**, energy of matter in motion, 63

larva (lär'və), **larvae** (lär've) (*plural*), the young form of a moth that has hatched from the egg, 85

learned act, a type of behavior acquired after birth, 16

lever (lev'ər), a simple machine consisting of a bar with a support (*fulcrum*) around which it can be turned, 156

lift, an upward force produced by difference in air pressure on the upper and under surfaces of the wing of an airplane, 212

light-year, a unit of measurement in astronomy equal to the distance light travels in one year, 385

lines of force, the pattern of the magnetic field describing the amount and direction of forces around a magnet or a conductor of electricity, 243

load, the weight to be lifted by a machine, 161

magnetic field, area in which magnetic lines of force can be noted around a magnet or a wire carrying electric current, 243

mass, the amount of matter in an object, 322

matter, all substances on the earth or in space, or any part of them; anything that has weight and takes up space

meteorite (mě'tē-ə-rīt'), a bit of matter that has fallen to the earth from space

metric system, a system of measurement in which each unit is multiplied by 10 to obtain the next larger unit, or divided by 10 to obtain the next smaller unit, 169

microorganism (mī'krō-ôr'gən-iz'əm), an organism generally too small to be visible without a microscope, 100

microphone (mī'krə-fōn), a device that changes sound waves into electric impulses

microscope (mī'krə-skōp), an instrument that enlarges the image of an object, so that it becomes visible

mineral (min'ər-əl), a compound in the soil or dissolved in water in the soil that aids the growth of plants, 102

mold, a fungus that grows on plant or animal matter, 104

molecule (mol'ə-kyōl), the smallest part of a substance that has the properties of the substance, 54, 197

motor nerve cell, a nerve cell (*neuron*) that carries a response to a muscle, 14

movable pulley, a pulley free to move; a system with a movable pulley multiplies the force applied to it, 167

mucus (myōō'kəs), a substance produced by cells lining the inside surface of the body and keeping them moist, 110

mutant (myōō'tənt), an organism different from its parents in one or more new traits that can be inherited, 347

mutant gene, a gene that has changed, resulting in a change in inheritance, 347

mutation (myōō-tā'shən), a new characteristic that can be inherited as a result of a change in the genes, 350

nerve, a bundle of nerve fibers, 12

nerve cell, 12; *see neuron*

nerve ending, the part of a nerve fiber where a nerve impulse begins or ends, 14

nerve fiber, the generally long threadlike part of a nerve cell, 9
 nerve impulse, a "message" (perhaps electrical or chemical) that travels along a nerve fiber, 9
 nervous system, the total of all the pathways along which nerve impulses may travel in an organism, 12
 neuron (nōōr'on), a cell which can carry a nerve impulse, 15
 neutron (nōō'tron), a particle in the nucleus of an atom, having no electrical charge, 288
 nova (nō'və), a star that explodes and increases greatly in brightness, 387
 nuclear reaction (nōō'klē.ər rē.ak'shən), a change in an atom or atoms as a result of fission or fusion; new atoms with different properties may be formed, 368
 nucleus (nōō'klē.əs), the central part of an atom, 232; also, of a living cell
 nylon (nī'lon), a man-made fiber having many of the properties of silk, 88

orbit (ōr'bit), the path of one body of matter around another, as a satellite around the earth or the earth around the sun
 ore, a mineral or rock that is the source of a metal
 organ, a group of tissues that carries on a specialized function in an organism
 organism, any living thing that carries on life functions
 ovary (ō'və.rē), in a flowering plant, the organ in which the seed is formed, 330
 oxide (ok'sid), a compound of oxygen and another element

penicillin (pen'ə.sil'in), an antibiotic produced by the mold *Penicillium*, 120
 physical change, any change in matter that does not change its chemical composition, 210
 pistil (pis'til), the part of a flower that contains the ovary at its base, 330
 piston, a device fitting snugly inside a tube, moved by steam or gases, and connected to a machine to do work, 200
 pitch, (*sound*) highness or lowness of a note on a scale; (*light*) placement in the spectrum according to frequency, 393

plastic (plas'tik), a man-made substance that can be molded, shaped, or cast, 82
 polio (pō'lē.ō), a virus-caused disease that damages nerve cells, 124
 polled (pōld), hornless, a result of a mutant gene in cattle, 355
 pollen (pol'an), powdery grain on the stamen of a flower; contains the sperm cell, 330
 pollinate (pol'ə.nāt), to transfer pollen from stamen to pistil of a flower, 330
 potential (pə.ten'chəl) energy, energy that is stored in an object by its position or chemical composition, 204
 pressure, force exerted on the surface of an object from without or from within
 prism (priz'am), a device, such as a triangular piece of glass, that separates light into its different wavelengths, visible as a spectrum, 372
 property, any characteristic that is generally true for a substance and for which the substance can be tested, as color, hardness, dullness
 proton (prō'ton), in the nucleus of an atom, a particle having a positive charge, 288
 pulley, a grooved wheel around which a rope may be placed, 158; *see also* block and tackle, fixed pulley, movable pulley
 pupa (pyōō'pə), the stage between larva and adult in the life of a moth, 85
 pure, in heredity, having a gene for a given trait from each parent, 332

quarantine (kwōr'an.tēn), the keeping of a person having a serious contagious disease away from others who might contract it, 140

radioactive (rā'dē.ō.ak'tiv), describes an element whose nucleus gives off particles and radiations, 287
 radio transmitter, a device that changes electric energy into electromagnetic waves and sends them through space
 rayon (rā'on), a fiber made from cellulose, 87
 reaction (rē.ak'shən), a force exerted in a direction opposite that of another force (action), 218; *see also* chemical reaction

reactor (rē-ak'tər), a device in which nuclear fission is controlled, 303

receiver, (*telephone*) a device for gathering electric impulses and changing them into sound waves, 261; (*radio and television*) a device for gathering electromagnetic waves from space

recessive (ri-ses'iv), a gene carried by the cells but whose effect does not appear as a trait in the organism, 333

reflex act, an act that is inborn, unlearned, automatic, 4

reflex arc, the nerve pathway followed by a nerve impulse from stimulus through connecting neurons in the spinal cord to response in a muscle or gland, 14

reservoir (rez'ər-vwôr), a lake, usually artificial, in which a city's water supply is collected and stored, 131

response, the reaction of an organism (or any part of it) to a change in the environment, 8

reward, something favorable obtained by an organism when it makes a useful or correct response to a stimulus, 16

sampling, a method of estimating the total amount by finding the average of small parts (samples) of the amount, 383

screw, a simple machine that multiplies effort. It consists of an inclined plane wound around a central post, 172

secrete (si-krēt'), to produce within a cell a substance that is used outside the cell, 110

sensory nerve cell, a nerve cell (neuron) that reacts to a stimulus and sends a nerve impulse to the spinal cord and brain, 14

serum (sir'am), the liquid part of the blood that remains after clotting, 127

simple machine, a single device for multiplying force or for changing its direction, as a lever, a pulley, an inclined plane, or a wheel and axle, 154

solution (sə-lōō'shən), a mixture of two substances, one of which is dissolved in the other, 51

sound wave, a form of mechanical energy in which particles of matter move back and forth in a characteristic pattern, 262

spark plug, a device to ignite a fuel in an enclosed chamber in an engine, 208

spectroscope (spek'trə-skōp), a device used to analyze light from a glowing object to determine its composition, 372

spectrum (spek'trəm), a band showing the separation of light, or electromagnetic, waves into their wavelengths, 372

sperm cell, a specialized cell in a plant or animal that, when united with an egg cell, can develop into a new organism; the male cell in reproduction, 330

spirilla (spī-ril'lə), **spirillum** (spīril'am) (*singular*), bacteria having a corkscrew or, rarely, a comma shape, 102

spore, a specialized cell of fungi and many nonflowering plants that can reproduce a new organism, 105

S-R bond, in behavior of organisms, the manner in which a stimulus is thought to be linked to a response, 18

stamen (stā'mən), the part of a flower that produces pollen, 330

state (of matter), any of the forms of matter; as, solid, liquid, gas

static electricity, an electrical charge (excess of electrons) on a substance, usually given it by friction, 234

stimulus (stim'yə-ləs), a condition in the environment that causes an organism to react, 8

streptomycin (strep'tō-mī'sin), an antibiotic produced by a mold, effective in treating tuberculosis, 121

subatomic particle, any particle of which an atom is composed, 315

supernova (sōō'pər-nō'və), an especially bright nova, 388

technology (tek-nol'ə-jē), the science of applying discovered concepts to the invention or improvement of materials or tools to do work, 55

telescope (tel'ə-skōp), an instrument that collects light from a distant object, focuses it as an image, and enlarges the image so that details can be seen

temperature (tem'pər-ə-čər), measurement of hotness or coldness; that is, the average kinetic energy of the molecules in a substance, measured in degrees

- tentacle** (ten'tə.kəl), in hydra and jellyfish, an armlike structure that aids the organism in catching food, 8
- theory** (thē'ər.ē), a reasonable explanation that satisfies a set of observations, data, or investigations, 18
- threads**, ridges around a screw that form a winding inclined plane, 173
- tissue** (tish'ōō), a group of similar cells that do one kind of work
- transmitter** (trans-mit'ər), a device for changing a form of energy into electric impulses and sending them along a wire, 261; or into electromagnetic waves and sending them out through space, 271
- turbine** (tūr'bin), a wheel which has blades that are moved by steam or other means and which is connected to another machine to do work, 201
- unlearned act; see reflex act**
- vaccinate** (vak'sin.āt), introduction of living or dead bacteria or viruses into the body to cause the body cells to produce antibodies, 126
- vaccine** (vak'sēn), a substance containing living or dead bacteria or viruses introduced into the blood to develop immunity to a disease, 127
- vertebra** (vūr'tə.brə), one of the small bones in the backbone through which the spinal cord passes, 146
- vertebrate** (vūr'tə.brit), an animal with a backbone, 146
- virus** (vī'rəs), a particle smaller than a bacterium (and not cell-like) that can reproduce itself inside a living cell and cause disease, 124
- volume** (vol'yōōm), measurement of the space occupied by a substance, 61
- watershed**, all the area from which water flows into and is collected by a lake, a river, or a reservoir, 133
- wedge**, a simple machine, consisting of an inclined plane that can be forced into or between objects to spread them apart, 174
- weight**, a measure of the pull of gravitation on an object
- wheel and axle**, a simple machine consisting of a wheel attached to a rod passing through its center, to which a force may be applied, 158
- white blood cells**, special cells in the blood that can engulf and destroy bacteria in the body, 113
- work**, the result achieved when a force moves an object through a distance, 183

INDEX

(Page numbers in **boldface** refer to illustrations.)

- accelerator, nuclear, 298, 299
- acid, 112
- acquired immunity, 127
- action, and reaction, 218, 220, 225
- adaptation, 38, **38**, 39, 39
- air, molecules of, 197, 198
- air pressure, 212, 213, **213**, 214, **214**
- aircraft carrier, nuclear, 310, 311
- airplane, 212, 214, **214**, 215, **215**, 216, **216**
- alchemist, medieval, 92, 92
- Algol, 374, 374
- alloys, 79, 80, 84, 93
- Alpha Centauri, 385
- alpha particles, 287, **287**, 297, **297**, 298
- aluminum, 48, **48**, 49, 52, 53, **53**, 55, 93; uses of, 52-53
- aluminum oxide, 49, 52, 53, 55
- Antares, 373, 378
- antenna: for radio, 271, **271**, 272; for satellites and waves from space, 277, **277**; for television, 274, **274**
- antibiotics, 121, **121**, 126, 141
- antibodies, 126, 127, **127**, 128, 141
- antiseptics, 111, 114, 141; effect on bacteria, 115, **115**
- Apollo spacecraft, 221, 222, **222**
- applied science, 55; *see also* technology
- Archimedes, 188
- armature, 253, 254, **255**
- association, 16, **16**, 17, **17**, 19, **19**
- astronaut, 94, 218, 221, 222, 268, **268**, 272
- atom(s), 54, 76, 82, 94, 232, 286, **286**, 288, **288**, 314; of carbon, 232, **232**, 289, **289**; of chlorine, 290, **290**, 320, **320**; of helium, 290, **290**, 368, 388; of iron, 289, **289**; of lithium, 288, **288**, 290, **290**; made of particles, 287, **287**, 288, 315-16; models of, 287, **287**, 288, 289, **289**, 293, **293**; new, made by bombardment of nuclei, 388, 390; of nitrogen, 289, **289**; nucleus of, *see* nucleus of atom; of oxygen, 289, **289**; of sodium, 320, **320**; structure of, 290, **290**, 291 (table), 292
- "atomic gun," 297, 298, **298**, 388, 390
- atomic number, 296, **296**
- atomic pile, 302, **305**, 310, 390; *see also* nuclear reactor
- atomic weight, 292; changes of, in fusion, 369
- attraction, resulting from opposite charges, 232, 233, **233**, 234, **234**
- automatic act, 21; *see also* habits
- automobile engine, 208, **208**, 209, **209**
- bacilli, 102, **102**
- bacteria, 100, **100**, 104, 108, 110, 126, 129 (table), 141; colonies of, 100, 101, **101**, 117; cultures of, 101, **101**; decay, 102, 108; defenses against, 110, 111, 113, 113-14, **114**, 118-22, 126; division in, 108, **108**; effect of antiseptics on, 115, **115**; effect of hydrochloric acid on, 112, **112**; food of, 108; infectious, 108, 110; kinds of, 100, 102, **102**, 113, **113**; as living cells, 104; pathogenic, 137; removed from drinking water, 131, 132, **132**, 133, 134, **134**, 135, 136; in soil, and nitrogen, 108; useful, 102; *see also* viruses
- bacteriologist, 117
- balloon, 212, 216, **216**
- balloon "machine," 196, **196**, 197, 198, **198**
- barn swallow, nest of, 4, 4
- Barnard's Star, 394, **394**, 395
- bauxite, 49, 52
- behavior, 4; *see also* habits, learning, reflex acts
- Bell, Alexander Graham, 261
- Benedict's solution, 106
- Bernoulli's principle, 214, 215, 219
- Bessemer converter, 78, **78**, 80
- bicycle wheel and axle, 158, **158**, 175
- biologist, 94

- birds, 146
- Black Death, 139
- blast furnace, 76, 77, 77
- blending traits, 342, 342-46, 344
- blinking, as inborn act, 4, 5, 5
- block and tackle, 166, 168, 168, 170, 170, 187, 187, 189; use of, 169, 169
- blood cells, white, 113, 113, 114, 114, 126
- Bohr, Niels, 287, 316
- bomb, nuclear 312, 368, 369
- boron, atomic nucleus of, 297
- Boulder Dam, 246
- bowline, how to tie, 25
- Boyle's Law, 392
- brain, 12, 12, 39, 41, 53, 151
- Braun, Wernher von, 55
- bread mold, 104, 105, 105
- breeding, *see* prize genes
- bronze, 76, 80
- brush, in electric motor, 253, 254, 255
- bud of potato, 326, 327, 327, 328, 328
- bull, Santa Gertrudis, 357, 357
- Burbank, Luther, 346

- cadmium control rods, 303, 304, 304, 305, 309
- camera, 274, 274
- cancer, radioactive substances in treatment of, 312, 312-13
- candle, burning, 206, 206, 207, 207, 208
- carbon, 75, 77, 78, 206, 208; atom of, 232, 232, 289, 289; atomic number of, 296, 296
- carbon dioxide, 75, 76, 77, 206, 210; formula for, 206, 208, 322; from burning fuel, 206; molecule of, 322; used by plants, 150
- carburetor, 208
- cast iron, 78
- caterpillar, 85, 85
- cattle, hybrid, 344, 345, 350, 350
- cell(s): blood, white, 113, 113, 114, 114, 126; cilia of, 111, 111; covering, 110; egg, in flowering plant, 330; nerve, *see* nerve cell; of potato bud, 328, 328; secretion by, 110; sperm, in pollen grain, 330
- cell membrane, 104, 107
- cell wall, 104, 107
- cellulose, 88, 88, 89
- Celsius scale, 67, 67
- Chain, Ernst, 121
- chain reaction, 302, 303, 303; control of, 303-04, 304, 305, 310, 312
- charcoal, 75
- chemical change, 210
- chemical energy, changed to heat energy, 60
- chemical reaction, 368, 368; in green plants, 150; matter neither gained nor lost in, 190, 322, 323
- chemistry, 82, 87, 90, 92
- chimpanzee, and learning process, 26-27, 27, 28
- chlorination of water, 132, 132
- chlorine, 132, 133, 136; atom of, 290, 290, 320, 320
- chlorophyll, 104, 329
- cholera, 131, 139
- chromosomes, 328, 330, 333, 360; DNA code in, 333, 334, 334, 359, 360, 405
- cilia, 111, 111
- circuit, electric, *see* electric circuit
- classifying animals and plants, 146, 148, 148
- cloud chamber, Wilson, 315, 315
- coal, 206, 279, 370
- cobalt, radioactive, 313
- cocci, 102, 102, 113, 113
- cocoon, 85, 85, 86
- code messages, 257, 260, 260, 261
- coke, 77
- colonies of bacteria, 100, 101, 101, 117
- color television, 275
- comets, 394
- compass, 268, 269
- compound machine, 177-78
- compounds, 49, 82, 321; obtaining metals from, 72, 72
- compressor, of jet engine, 218, 219
- concepts: formulated by scientists, 53, 54, 55, 56, 64, 90, 93, 94, 148, 151; uses of, 57-65, 58, 59, 60, 61, 62, 63, 64, 65, 90
- conditioning, 18, 22; theory of, 30
- conductor of electricity, 235
- connecting nerve cell, 14, 15

- contact point, in electric bell, 252, 253
 contagious disease, 136, 140
 control, 11, 119, 141, 326, 327, 327, 328
 control rods, in reactor, 303, 304, 304, 305, 309
 copper, 49, 51, 52, 73, 80; discovery of, 70, 71, 73, 74; separated from its ore, 72, 72, 73, 74, 75, 76
 copper carbonate, 72, 74, 76
 copper ore, 70, 71, 72, 73, 74, 76
 copper oxide, 70, 72, 74, 75, 76
 copper sulfate, 49, 50, 51, 52
 corn, hybrid, 344, 344, 345
 corrosion, 79, 80; of tin can, 81, 81; *see also* rust
 cotton, 86, 87, 93
 cotton gin, 86
 covering cells, 110
 Crab Nebula, 390, 390
 crane, hand-operated, 176, 177
 cross-pollination, 336, 336, 337, 337, 340, 340; investigation into, 338, 338, 339, 339
 cryogenics, 66
 cryolite, 52
 cultures of bacteria, 100, 101, 101
 cuprite, 71
 Curie, Marie, 286, 297, 312, 315
 Curie, Pierre, 286, 312
 current electricity, 235-36, 237, 237, 268, 270; as flow of electrons, 236, 240, 243; generating, *see* generator(s); investigations into, 237, 237, 239, 239, 241, 241, 269, 269; for telegraph, 258, 258
 cyclotron, 298, 298, 299, 390
 cylinders, in automobile engine, 208, 208, 209, 209

 Dalton, John, 49, 54, 286, 314-15
 Da Vinci, Leonardo, 216
 "dawn horse," 352, 352
 decay bacteria, 102, 108
 Democritus, 286, 314
 diastase, 106, 106, 107, 122
 digestion: defined, 107
 digestive juices, hydrochloric acid in, 112
 dinosaurs, 353, 361
 diphtheria, 125, 136, 140
 diseases under control, 129 (table)
 distance, and work done, 184, 186-87, 198, 198
 DNA code, 324, 333, 334, 344, 359, 360; changing, 346-48, 350, 352-53, 355, 405
 DNA molecule, 328, 336, 359, 360
 dominant trait, 333, 340, 343
 door bell, *see* electric bell
 doorknob, as wheel and axle, 175, 175
 Doppler effect, 393, 394, 394, 404
 dry cell, 50, 50, 51, 269

 Echo I, 275
 Edison, Thomas, 55
 efficiency in machine, 202
 effort, in simple machines, 161, 161, 163, 170
 egg cell, in flowering plant, 330
 Einstein, Albert, 323
 electric bell, 248, 248, 249, 249, 250, 251, 252; explanation of, 252-53; model of, 250, 251
 electric circuit, 244, 245, 245, 248; broken, 252, 253
 electric current, in copper plating, 51, 51, 52, 53; in obtaining aluminum, 52, 53; *see also* current electricity
 electric energy, 189, 189, 236, 252, 279; from nuclear power plant, 308, 309; *see also* electricity
 electric impulse: in radio transmission, 271; in telephone, 262, 264, 264, 266, 270, 271; in television, 274
 electric motor, 248, 249, 249; explanation of, 253; model of, 253, 254, 255, 255
 electric signals, 257
 electricity: conductor of, 235; current, *see* current electricity; static electricity
 electrolysis, of water, 366, 366, 367
 electromagnet, 244, 244, 245, 245, 246, 246; circuit in, 244, 245; in electric bell, 249, 249, 250, 251, 252, 252, 253; in electric motor, 253, 254, 255; in telephone, 263, 264
 electromagnetic waves, 270, 270, 271, 271, 273, 275, 276, 280; from outer space, 276-77

- electron microscope, 124, 129
- electrons, 232, 235, 288, 289, 289, 290, 290, 291 (table), 292, 322; flow of, in electricity, 236, 240, 243; in motion around atomic nucleus, 232, 316, 316; negative charge of, 232, 288; transfer of, 232
- elements, 49, 82, 291 (table), 321; and atomic number, 296, 296; new, made by bombardment of atomic nuclei, 388, 390; number of, 321, 321, 322, 388; origin of, 388, 390, 391, 398; in stars, and spectrum, 373, 373
- embryo of plant, 330
- Enders, John, 127
- energy: from burning fuel, 202, 206, 206, 224-25; changed from one form to another, 189, 189, 190, 209, 225, 236, 279-80, 405; changed to heat energy, 60; electric, *see* electric energy; kinetic, *see* kinetic energy; matter changed into, 322-23, 370, 372, 387; from nuclear reactions, 305, 308, 309; potential, *see* potential energy; and work, 189, 189, 197, 238
- engine: automobile, 208, 208, 209, 209; jet, 212, 218, 218, 219; Hero's, 203, 203; rocket, 220, 220, 221, 221
- environment: adaptation to, 38, 38, 39, 39; changed by man, 39-41, 40, 41, 53, 91-94, 140, 140, 151; control of, 139-41, 140; dinosaurs fail to change with, 353; effect of, on living things, 326, 326, 327, 328, 329; and heredity, 329, 359; interdependence with, 39, 148-51, 149, 150, 329
- enzymes, 107
- evaporation, of gasoline in carburetor, 208
- experiment, as scientific tool, 118
- explosion, 205-06, 208
- Fahrenheit scale, 67, 67
- fibers, new, invention of, 86, 87, 88, 90, 93
- filtration of water, 132, 132, 135
- fish, training of, 19, 19; nest building by, 6
- fission, nuclear, 294, 294, 295, 295, 296, 297, 298, 298, 302, 304, 316, 369
- fixed pulley, 158, 159, 159, 166, 166
- Fleming, Alexander, 106, 117-21, 119, 120, 122, 141
- Florey, Howard, 121
- flowering plants, 148, 330, 330, 332, 336, 336, 337, 337, 338, 338, 339, 339
- fluids, pressure of moving, 212, 213, 213, 214; *see also* force
- food-gatherer, 70, 92, 92
- food-making by green plants, 150, 150
- food-producer, 70, 92, 92
- force, 155, 198, 212; direction changed by machine, 158, 159, 159; of friction, 180, 181, 181, 182; of moving molecules, 198, 198, 200; multiplied by machine, 155, 155, 156, 156, 157, 157, 173, 173, 174, 175, 175, 185, 185, 186, 187, 187; of steam, 200, 200, 205, 205
- four o'clocks, heredity in, 342, 343, 343, 344, 360
- frequency: of light waves, 393, 394; of sound waves, 393
- friction, 180, 182; investigation into, 181, 181
- fruit flies: bombarded with X rays, 352; DNA code in, 334, 334; kinds of, 351, 351; mutations in, 350, 352
- fuel: energy from burning, 202, 206, 206, 224-25; for rocket, 221
- fulcrum, 156, 156, 157, 157, 161, 161, 163; location of, 162, 162
- fungi, 104, 105, 105
- fusion, nuclear, 316, 368, 368, 369, 369, 387, 398
- galaxy, defined, 381
- Galileo, 398
- galvanometer, 239, 239, 241, 241, 243
- gases: compression of, 389, 389; kinetic energy of, 198
- gasoline, 93, 206, 208, 209, 210; model of molecule of, 208
- gear wheel, 176, 176
- Geiger counter, 300, 300, 313
- generator(s), 189, 189, 202, 237, 237, 238, 239, 239, 240, 240, 242, 243, 245, 246; at Hoover Dam, 244, 245

genes, 328, 329, 330, 332, 333, 333, 336, 337, 360, 405; changed in fruit flies, 350, 350, 352; and DNA code, *see* DNA code; dominant, 340, 342, 343, 344, 361, 361; mutant, 347, 350, 352-53, 355, 356, 357, 361; prize, *see* prize genes; recessive, 340, 342, 343, 344, 361, 361

genetic code, *see* DNA code

geneticist, 344

giant stars, *see* stars

gland(s): salivary, 14, 15; thyroid, 313

glucose, 150

goal-insight in learning, 26, 28, 30

Goddard, Robert, 216

gold, 80, 82, 92

government, role of, in health, 136

grafting, 348, 348, 349, 349

Grahame-White, Claude, 216, 216

gram, 169

graphite, in nuclear reactor, 304, 304

Gravitation, Newton's Law of Universal, 397, 398

green plants, 139, 150, 150

guinea pigs, heredity in, 342, 342

habitat, 38

habits, 21-22; forming, 23, 23-26, 24, 25; practice in fixing, 33, 33, 34; study, 32-37, 33, 36

halazone pills, 134

Hale telescope, 380, 381

Hall, Charles Martin, 48, 49, 52, 53, 55, 73

Halley's comet, 394

health, public, 131-37

heat, 57; changed into chemical energy, 60; changed into mechanical energy, 189, 189; investigation into nature of, 59, 59; kinetic theory of, 63, 63; as motion of molecules, 61, 62, 198; from nuclear energy, 305, 308, 309, 308-09; from sun, 279; and temperature, 374, 375, 376

helium, 212; atom of, 290, 290, 368, 369, 388; atomic nucleus of, 297, 297; atomic weight of, 369; fusion of hydrogen into, 368, 369, 369, 370, 372, 387, 398; in sun, 369, 370, 372, 387

heredity, 326, 398; and environment, 359; and intelligence, 360; *see also* DNA code;

Mendel, Gregor; traits

Hereford cattle, 355, 356

Hero's steam engine, 203, 203, 218

Hoffman apparatus, 367, 367

Hoover Dam, 244, 244, 245

hornlessness (a mutant trait), 355, 356, 356

humus, 102, 102

hybrid, 344, 344, 345, 350, 350

hydra, 7-9, 8, 9

hydrogen, 208, 366, 367, 388; atomic nucleus of, 297; atomic weight of, 369; fusion of nuclei of, 368, 368, 369, 369, 370, 372, 387, 398; in sun, 369, 370, 372, 387; symbol for molecule of, 366; from electrolysis of water, 206, 321, 366, 367, 368

hydrogen bomb, 368, 369

hypothesis, 119

immunity, 126, 127

inborn acts, 4, 6, 6-7, 7, 16, 16; *see also* reflex acts

inclined plane, 154, 154, 186; investigations into, 155, 155, 173, 173, 185, 185; winding, 172, 172, 173, 173

infection, 108, 110, 113, 113

influenza, 124

inheritance, *see* heredity

insects, cross-pollination by, 337

insight into achieving goal, 26, 28

instinct, 6

insulator, heat, 62, 62

intelligence, inheritance of, 360

interdependence, 39, 146-51, 149, 150

invertebrates, 146, 148

investigation, art of, 409-21

iodine, radioactive, 313

iron, 74, 75, 75, 76, 79, 80, 90, 93; atom of, 289, 289; cast, 78; an element, 76, 82; furnaces for making, 76, 77, 77-78, 78; separated from ore, 75

iron lung, 125, 125

iron ore, 71, 73, 75, 77, 78

- iron oxide, 71, 77, 78, 79, 190, 321; *see also* corrosion
isotopes, 302
- jack, force multiplied by, 156
jet plane: engine of, 212, 218, 218, 219;
speed of, 257
- kerosene, 218, 219
kinetic energy, 63, 196, 197, 198, 225, 374,
376; potential energy changed into, 208
kinetic theory of heat, 63
kitchen middens, 68, 68
knee reflex, 12, 13, 13, 14, 14, 15-16
krypton, nucleus of, 296
- larva, 85, 85
Lavoisier, Antoine, 314
Lawrence, E. O., 298
lead, 73, 92
learning (learned acts), 16, 16-18, 17; au-
tomatic, 21; and environment changed
by man, 39-41, 40, 41, 53, 91, 92, 94,
140, 140, 151; goal-insight theory of, 26,
28, 30; investigations into problems of,
29, 29, 30, 33, 33; study habits formed
in, 32-37, 33, 36; and theory of con-
ditioning, 30; by trial and error, 74, 76,
80, 92
Leucippus, 286, 314
lever, 156, 156, 161, 161, 163, 163; inves-
tigations into, 157, 157, 162, 162
lift of airplane, 212, 215
light waves: frequency of, 393, 394; speed
of, 257, 323
lightning, 235, 235
light-year, 385
lima bean plant, 329, 329
lines of force, 243, 243, 268, 269
liquid oxygen, for rocket, 221
lithium: atom of, 288, 288, 290, 290; nu-
cleus of, 297, 297
load, and lever, 161, 161, 162, 162, 163
locomotive, steam, 201
longhorned cattle, 347, 347
Lunar Orbital Rendezvous, 221, 222
- machines: compound, 177; and energy,
189-90; speed multiplied by, 158; simple,
154, 155
magnesium, 48
magnet, 239, 240, 240, 241, 241, 242, 243,
243, 245; lines of force of, 243, 268
magnetic field, 243, 243, 268, 269, 270, 270
malachite, 72, 74, 76
malaria, 140
mammals, 146
Manx cat, 355, 355
Marconi, Guglielmo, 55, 268
Mars: electromagnetic waves from, 276;
orbit of, 378, 378
mass, 322
mass-energy, and Einstein's formula, 323
matter: changed into energy, 322-23, 370,
372, 387, 405; changed from one form
to another, 190, 405; composed of par-
ticles, 57, 60, 92, 151, 314-16, 322; force
exerted by, 198
measurement, 141; of distance of stars, 376,
377, 377
meat grinder, as compound machine, 178
medical research, 141
medicine dropper, 100
Meister, Joseph, 99, 124, 127
memorizing, best place for, 35
Mendel, Gregor, 333, 342, 398
mercury, 73
Mesabi range, 78
metabolism, 144
metal(s): discovery of, 69, 70-71, 73; get-
ting from compound, 72, 72; methods of
working, 80; separated from ores, 72,
72, 73, 74, 75; *see also* aluminum; iron
metallurgy, 76, 80
meteorite, 74
meteorologist, 413
meteorology, 415
metric system, 169
microorganism(s), 100, 139; *see also* bac-
teria
microphone, 270, 271, 271, 273
microscope, 100, 129, 139, 141; electron,
124, 129
milk, safe to drink, 131

Milky Way Galaxy, 381, 384, 384, 385, 385, 394, 397
 minerals, in soil, 102
 mining, 80
 model(s): of atomic nucleus, 294, 302; of atoms, 287, 287, 288, 289, 289, 293, 293; of electric bell, 250, 251; of electric motor, 253, 254, 255, 255; of molecules, 82, 82, 88, 208, 208; of nuclear reactor, 306, 306; of steam engine, 199, 199, 200, 200; of telegraph, 258, 259, 259; of telephone, 263, 263; of turbine, 201, 201
 moisture, a need of fungi, 104
 molds, 104, 108, 117, 118, 120, 121, 121, 148
 molecules, 54, 82, 94, 197; of air, 197, 198; models of, 82, 82, 88, 208, 208; motion of, 58, 58, 60, 61, 62, 198, 199, 199, 200, 225, 374; *see also* DNA molecule
 Monkey (bull), 357, 357
 Montgolfier, Joseph and Jacques, 216, 216
 moon, landing capsule for, 221, 222, 222; surface of, 404
 Morse, Samuel F. B., 261
 Morse Code, 260, 260, 268
 moth, life history of, 85, 85
 motor, electric, *see* electric motor
 motor nerve cell, 14, 15
 Mount Palomar, 380, 381
 movable pulley, 167, 167, 168
 mucus, 110, 110, 111
 Muller, Hermann, 350, 352
 muscles, machines to multiply force of, 154, 154
 mutants (genes, mutations), 347, 350, 350, 352-53, 352, 355, 356, 357, 357, 361
 natural immunity, 126
 negative charge, 232, 288
 neptunium, 388
 nerve cell(s), 12, 12, 125; connecting, 14, 15; motor, 14, 15; and polio virus, 125, 125; sensory, 14, 15
 nerve endings, 14
 nerve fibers, 9, 14, 14, 15
 nerve impulse, 9, 14
 nerve net, of hydra, 9, 9
 nervous system, 12, 12

nest-building, 4, 4, 6, 6
 neuron, *see* nerve cell
 neutrons, 288, 289, 289, 290, 290, 291 (table), 292, 294, 316, 322; used for splitting nuclei of atoms, 295, 295, 297, 302, 304, 310
 Newton, Isaac, 54, 218, 224, 228, 397, 398
 nitrogen: atom of, 289, 289; atomic number of, 296; and bacteria in soil, 108
 Nobel prize, 121, 352
 North Star, 395, 397, 397
 nova, 387, 387, 388, 398
 nuclear accelerator, 298, 299
 nuclear aircraft carrier, 310, 311
 nuclear bomb, 312, 368, 369
 nuclear energy, 305, 308-11
 nuclear fission, 294, 294, 295, 295, 296, 297, 298, 298, 302, 303, 304, 316, 369
 nuclear fusion, 316, 368, 369, 387, 398
 nuclear power plant, 308-09, 308-09, 310, 310
 nuclear reaction, 302-06, 303, 368, 368; mass-energy remains same in, 322-23; *see also* nuclear fission, nuclear fusion
 nuclear reactor, 303-06, 304, 305, 308, 310, 311, 312; building, 303-06; model of, 306, 306; *see also* atomic pile
 nuclear submarine, 310, 311, 311
 nucleus of atom, 232, 280, 288, 288, 292, 316, 316; radioactive, medical uses of, 312, 312-13; splitting, 294, 294-99, 295, 297, 298; unstable, 299
 nylon, 88, 89, 93; molecule of, 88
 observation, in science, 141, 151
 Oersted, Hans, 268
 orange, seedless, 346, 347, 348
 organism(s), 100; changes in, 361; as product of heredity and environment, 359
 ovary, in flowering plant, 330
 oxygen: in aluminum oxide, 49; atom of, 289, 289; in carbon dioxide, 206, 208; in chemical reaction in green plant, 150; in iron oxide, 77, 78, 79; symbol for molecule of, 366; from water, 206, 208, 321, 366, 367, 368

- particles, atomic, 287, 287, 288, 315–16
- Pasteur, Louis, 54, 99, 127, 141
- pasteurized milk, 131
- pathogenic bacteria, 137
- Pavlov, Ivan, 18
- payload, of rocket, 220
- pea plants, heredity in, 332, 333, 333, 336, 336, 337, 340, 340, 342, 342
- penicillin, 120, 121
- Penicillium*, 118, 119, 120
- photosynthesis, *see* food making in green plants
- physical change, 210
- physicist, 94
- picture tube, television, 275
- pistil, 330, 332
- piston, 200, 200, 201, 209
- pitch of sound, 392–93, 393
- pith balls, 236, 238, 238
- planets, life on other, 277
- plants: adapted to environment, 38, 38; carbon dioxide for, 150; classifying, 147, 148; cross-pollination of, *see* cross-pollination; flowering, 148, 330, 330, 332, 336, 336, 337, 337, 338, 338, 339, 339, 340, 340, 342, 342; green, 139, 150, 150; mutant, 347, 348, 349, 349, 357; nongreen, 104; prize genes in, 358; pure, 332, 333, 340, 344
- plastics, 82, 84
- plutonium, 388
- Polaris (North Star), 395, 397, 397
- police signals, 272
- polio, 124–25, 126, 127, 128, 136, 140
- polled cattle, 355, 356, 356
- pollen, 330, 332, 337
- pollination, 330
- positive charge, 234, 288
- potato: effect of environment on, 326, 327, 327, 328, 328, 329; Katahdin, 357
- potato blight, 357
- potential energy, 208, 225
- practice, in fixing habit, 33, 33, 34
- pressure of moving air, 212, 213, 213, 214
- Priestley, Joseph, 314
- prism, 372
- prize genes: for hornlessness, 356; in plants, 358; search for, 355–58; for shorthorned cattle, 348, 350
- propagation of plants, 347, 348
- propeller: of airplane, 212; of steamship, 202, 202
- protons, 288, 289, 289, 290, 290, 291 (table), 292, 294, 322; as atomic bullets, 297, 298; and atomic number, 296, 296
- psychologist, 7
- pulley, 158, 165; fixed, 158, 159, 159, 166, 166; movable, 167, 167; uses of, 165, 165, 166, 166, 167, 167
- pupa, 85, 86
- pure plant, 332, 333, 337, 340, 344
- pure science, 55
- pyramid of life, 149, 149, 150

- quarantine, 140

- rabies, 99, 124, 127
- radio (radio waves), 268, 270; lives saved by, 272; reception of, 271–72; transmission of, 270–71, 272, 273
- radio telephone, 272
- radio telescope, 381
- radioactivity, 287, 312, 313; investigation into detection of, 300, 300
- radium, 286–87, 297, 299, 312, 315
- ramp, as inclined plane, 172, 172
- rats, care of young by, 9
- rayon, 87, 87, 93
- reaction, 218, 220, 225; *see also* chemical reaction; nuclear reaction
- reactor, nuclear, *see* nuclear reactor
- receiver, telephone, 261, 262, 264, 264, 265, 265, 266
- recessive trait, 333, 340
- red shift, 394, 394
- reflex acts, 4, 16, 16; complex, 6; conditioned, 18; investigation into, 13, 13; *see also* inborn acts; learning (learned acts)
- reflex arc, 14, 14, 15
- relay stations, in space, 275–76, 276, 277
- research, 137
- reservoir, 131, 131, 133
- response to stimulus, 8, 12, 13, 23
- reward, in learned act, 16, 17

- rocket engine, 220, 220, 221, 221
- rocket missile, 311
- root stock, 348
- rust (disease), 358
- rust (iron oxide), 71, 77, 78, 79, 190, 321;
see also corrosion
- Rutherford, Ernest, 287

- Sabin, Albert, 128
- saliva, 14, 110
- salivary glands, 14, 15
- Salk, Jonas, 55, 128, 141
- Salk vaccine, 128, 128
- sampling, 382, 382-83, 383, 384-85
- Santa Gertrudis bull, 357, 357
- satellites, transmitters in, 272, 275-76, 277
- science: applied, 55 (*see also* technology);
environment changed through, 91, 94,
151; laws of, 397-98; modern, birth of,
398; pure, 55; technology in partnership
with, 90, 91, 93, 94, 129, 151, 280
- scientists: concepts formulated by, 53, 54,
55, 56, 64, 90, 93, 94, 148, 151; experiment
as tool of, 118; as student, 37; measure-
ment by, 141, 377; observation by, 141,
151; phenomena studied by, 280; ques-
tions asked by, 53-54; tools invented by,
53, 54, 55
- scissors, as compound machine, 177
- scratching reflex, 16, 16
- screw, 173, 173
- screwdriver, 161
- secretion, by cells, 110
- seedlessness, 346, 347, 348
- seeds, 329, 330, 330, 332, 337
- seesaw, 161, 161
- sensory nerve cell, 14, 15
- serum, given to Meister, 127
- shorthorned cattle, 347, 348, 349
- silk, 86, 87, 88; model of molecule of, 88
- silk moth, 85, 86
- silver, 50, 51, 80, 82
- simple machine, 154, 155
- skin, as defense against bacteria, 110
- smallpox, 125, 126, 127, 136, 139, 140
- solar system, 391, 398, 399
- solid fuel, for rocket, 221
- sound waves, 262, 262, 266, 270, 272, 392,
392; frequency of, 393; and pitch, 392-
93, 393; speed of, 392
- sounder bar, of telegraph, 258, 258
- space, radio transmission from, 272, 277,
277; relay stations in, 275-76, 276, 277
- space capsule, 94, 218, 218, 220, 221, 268,
268
- spacesuit, 94, 94
- spark plug, 208, 209, 218
- spectroscope, 369, 372, 372, 378, 393
- spectrum, 372, 373, 373, 393, 394
- speed, machine to multiply, 158, 159
- sperm cell, in pollen grain, 330
- spider web 6, 6, 7
- spinal cord, 12, 12, 14, 14
- spirilla, 102, 102
- spores, 105, 105, 108
- S-R bond, 18, 22
- stages of rocket, 220, 221
- stainless steel, 79
- stamen, 330, 332
- Staphylococcus*, 113
- starch, 107
- stars: colors of, 373, 373, 378; dark, 374;
giant, 378; heat of, 376; motions of, 392,
393, 394, 394, 395, 397; nuclear fusion
in, 387, 398; number of, 380-81, 381, 384,
385; photographs of, 384, 394; sampling
as method of counting, 384, 384-85;
sizes of, 376, 378, 378; spectra of, 373,
373; temperatures of, 373, 373, 376, 378;
see also nova; supernova
- static electricity, 234-35
- steam, 200, 205, 210
- steam engine, 200, 200, 201, 202; Hero's,
203, 203, 218; toy, 199, 199, 200, 200
- steam pressure, 200, 200, 205, 205
- steamship, turbine of, 202, 202
- steel, 76, 77, 78, 79, 80; stainless, 79
- steer, longhorned, 347, 347
- stimulus, 8, 12, 13, 14, 23; reward associated
with, 16, 16, 17, 17, 19, 19
- streptomycin, 121
- study habits, formation of, 32-37, 33, 36
- subatomic particles, 315
- submarine, nuclear, 310, 311, 311

- sun, 365, 378, **378**, 394; diameter of, 376, 387; distance from Earth, 279, 369, 370, 372, 376, 378; as energy source, 149, 150, 279, **279**, 366, 369, 370, 378; helium in, 369, 370, 372, 387; hydrogen in, 369, 370, 372, 387; nuclear fusion in, 369, 370, 372, 387; plants and animals dependent on, 149, 150, 370, 378; temperature at surface of, 372, 373, 378; volume of, 387
- sunlight, effect on plants, 329
- supernova, 388, **388**, 390, 398
- switches, electric, 248, **248**
- synthetic fibers, 86, 87, 88, 90, 93
- technology, 55, 90, 92; environment changed through, 91–94, 151; science in partnership with, 90, 91, 93, 94, 129, 151, 280
- telegraph, 257, 258, **258**; invention of, 261; model of, 258, 259, **259**; use of, 260, **260**, 261
- telegraph key, 258, **258**, 259, **259**
- telephone, 261, **261**, 264, **264**, 266, **266**; explanation of, 262, 264, 266; investigation into, 265, **265**; model of, 263, **263**; parts of, 261, 262, 264, **264**, 266, **266**; radio, 272; special long-distance, 261, **261**
- telescope: Hale, 380, 381; radio, 381
- television (television waves), 272, 273, 275, 276, 279; color, 275; reception of, 274; transmission of, 273, **273**, 274, 275, **275**, 276
- television camera, 274
- Telstar, 275
- temperature: expansion resulting from, 61; and heat, 374, 375, 376; as need for growth of fungi, 102; and spectrum, 373, **373**; of stars, 372, 373, **373**
- tentacles, of hydra, 8, 8
- textiles, 86–88
- theory, 18
- threads on screw, 173, **173**
- thrust of rocket, 221
- thunderstorm, 235
- thyroid gland, 313
- tin, 76, 80, 81
- tomato plant, “wilt” in, 357, **357**, 358
- tools: invention of, 53, 54, 55, 69, 70; and new fibers, 84, 86, 87; and new metals, 68, 68–70, 69, 70
- traits: blending, 342, 342–46, **344**; and DNA code, 328, 333, 334; dominant, 333, 340, 343; and environment, 329; inheritance of, 326, 332–34, **334**, 359, 360; recessive, 333, 340
- transmitter: radio, 271, 272; telephone, 261, 262, 264, **264**, 265, **265**, 266, **266**, 271; television, 273, **273**, 274
- trial and error, 74, 76, 80, 92
- tuberculosis, 121, 131, 137, 139
- turbine, 189, 189, 201, 202, **202**, 242, **242**, 244, 308, 309, 310; model of, 201, 201
- typhoid, 126, 131, 137, 139
- Universal Law of Gravitation, Newton’s, 397, 398
- universe: expanding, 394; vastness of, 395
- unlearned acts, *see* inborn acts; reflex acts
- uranium, 287, 291 (table), 299, 310, 369; nucleus of, 295, **295**, 296, 299, **299**, 302, 308
- uranium-235, 304
- uranium-238, 304
- vaccination, 126, 136, 140
- vaccine, 127; against polio, 128, 128
- vacuum, as insulator, 62
- vegetative propagation, 332
- vertebrae, 146
- vertebrates, 146
- viruses, 124, **124**, 125, **125**, 126, 127, 128, 129 (table), 141
- Waksman, Selman, 121
- water: formula for, 206, 208, 210, 366, 367; purification of, 131–37, 132, 134, 137, 140
- watershed, 133
- Watt, James, 205
- weather, 415–19
- wedge, 174, 174
- well, 133, 135, **135**
- wheel and axle, 158, **158**; examples of, 175, **175**, 176, 176; *see also* gears

white blood cells, 113, 113, 114, 114, 126
Whitney, Eli, 86
Wilson cloud chamber, 315, 315
wilt disease, 357, 357, 358
wing of airplane, 214, 214, 215
wire, for telephone message, 261, 262
work, 183-84, 190, 198, 238, 252; and en-
ergy, 189, 189, 197, 238

Wright, Wilbur and Orville, 216

X rays, genetic code changed by, 352

Yankee Atomic Electric Power Plant, 308,
308

yeast, 144





